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The Germination of Rice Seeds in Ceylon

BY

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This paper is an account of investigations, carried out at Peradeniya during the last two years, into some of the problems connected with the germination of rice seeds. It was found necessary in the first place to develop a satisfactory technique of testing; after this was done experiments were started to obtain evidence on

- (i) The length of the resting period in *Maha* (long-aged) and *Yala* (short-aged) paddies and the effect of the local custom of "smoking" in curtailing this period.
- (ii) The age of paddy seed and its effect on the rapidity of germination.

During the course of these experiments it was noticed that dark-glumed seeds took longer to germinate than those with light glumes. Accordingly evidence on the effect of glume colour on germination was also obtained.

Certain problems are still to be attempted; one of these, of certain practical importance, is the effect on viability of keeping the seed an extra year before sowing. Under some conditions seed may be kept for this extra year. In Ceylon, however, unless such seed is stored so as to prevent attack by paddy moth or grain weevils, it is of very little use for sowing. The problem of safe storage of paddy seed is mentioned here only because it has been found that naphthaline has a deterrent effect on moth. Whether the use of the small quantities of naphthaline for this purpose has any detrimental effect on the viability of the seed is, along with the other problem mentioned, at present under investigation. Certain germination tests with rice are open to a small error in that the different varieties being tested may not have been harvested at the same stage of maturity. Kondo (1)¹ has shown that the stage of maturity of the seed affects the length of the

1. Figures in brackets refer to literature cited, a list of which will be found at the end of this paper.

resting period. In the experiments described in this paper the seeds used were all harvested, so far as possible, at the same stage of maturity, *i.e.*, when they were dead ripe. All seeds, moreover, were sun-dried after threshing.

THE METHOD OF CONDUCTING GERMINATION TESTS

Various methods of conducting germination tests may be used. Mitra and Gangully (2) describe a method of testing on blotting paper spread over moist saw-dust, with moist blotting paper covering the seed, the whole being within a rat-proof wooden box. The methods tried at Peradeniya were as follows:—

- (1) Porous dishes containing no standing water.
- (2) Porous dishes containing standing water.
- (3) Moist sterilised sand.

In the above three methods the seeds were washed in a one in a thousand solution of mercuric chloride to retard the development of moulds.

- (4) Porous dishes containing standing water and with the seeds not washed with mercuric chloride.

The porous dishes used were $2\frac{3}{8}$ " square, about $\frac{1}{2}$ " high and with a $\frac{1}{4}$ " rim which keeps the seeds on the dish and which will, if necessary, retain standing water on the dish. Such dishes may be seen in the catalogues of makers of scientific instruments.

These dishes were placed in a zinc tray which could be securely fastened at night to prevent damage by mice and rats. Small air holes were pierced in the sides of the zinc trays. Trays may be made as large as is desired if precautions are taken to keep the bottom of the trays level. Such precautions are necessary as the dishes in the trays stand in about a quarter of an inch of water. This water in the trays keeps the porous dishes moist enough to ensure germination. Each dish will hold 100 seeds and in ordinary tests, two dishes, or 200 seeds, are used for each test. The experimental errors of tests in porous dishes, with no standing water and with the seed washed in mercuric chloride, calculated from twenty-seven degrees of freedom, were for 50 seeds 2.28%, for 100 seeds 1.6% and for 200 seeds, 1.14%. When tests were carried out in porous dishes the seeds in the dishes were covered with water for 24 hours. At the end of that period the water was either completely or partially removed depending upon the method being tried. The comparative efficiency of the four different methods may be judged from Text fig. 1. Washing the seeds in mercuric chloride was very successful. It is always useful and is essential in damp weather and with old seeds. Moist sterilised sand gave good results but not so good as the porous dishes. With porous dishes standing water in the dishes is

not advisable. In the experiments described below tests were carried out on porous dishes without standing water and with washed seed.

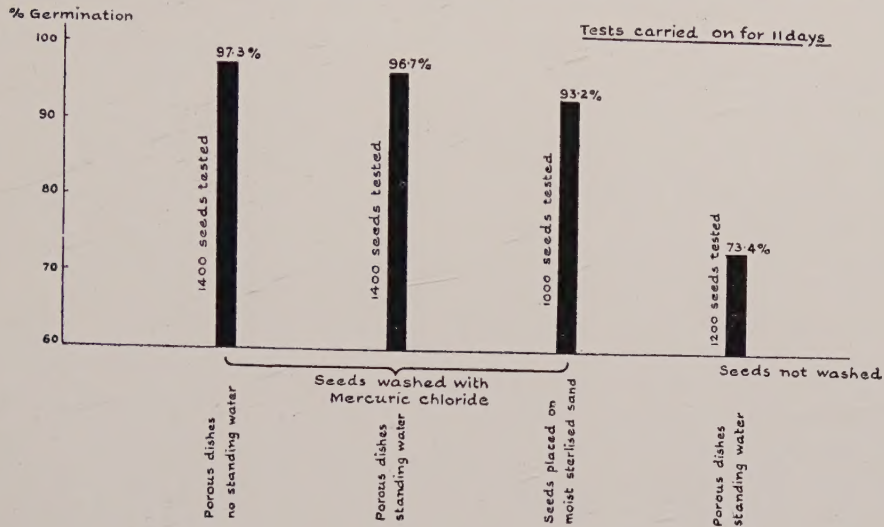


Fig. 1—The efficiency of different methods of testing the viability of Paddy seeds.

Lids of trays were kept closed until the radicles of the seeds had started to develop, after that they were kept open during the greater part of the day. Seeds were removed from the dishes only after both the plumule and radicle had appeared.

The duration of an ordinary germination test was fixed at ten days. Normally, in Ceylon, villagers' paddy seed is germinated under pressure. Germination is generally complete within from five to eight days. After from six to eight days seeds start to rot. It was considered advisable, therefore, to stop germination tests on the tenth day, the extra two days being given as an offset to the lack of pressure which is supposed to hasten germination.

The use of porous dishes would seem to have certain advantages over blotting paper and saw-dust. The seeds are always exposed to view and one variety can be counted without disturbing the rest. Sterilising the dishes and trays at the end of each test is very simply done by washing with mercuric chloride. There is, moreover, no chance of the seeds of one dish being mixed with the seeds of another.

THE VIABILITY OF PADDY SEED IMMEDIATELY AFTER HARVEST

In certain districts in Ceylon, where two crops are grown in the year, the seed harvested at the end of one season is sown at the beginning

of the next after being in storage for only a short time. The cultivator increases the germination percentage of such seed by "smoking," that is, by placing a bag of seed in the smoke of the kitchen fire. Tests were

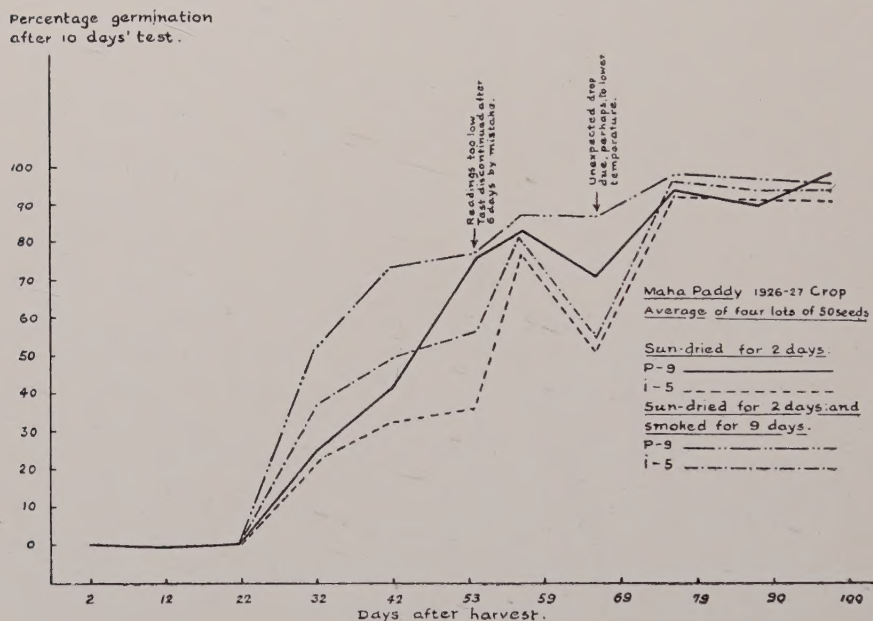


Fig. 2.—Maha Paddy seed. Age and Viability

laid down to determine with both *Maha* and *Yala* paddy the resting period which may be expected under Ceylon conditions, and also, the effect of smoking on curtailing that resting period. Two pure-line *Maha*, and two pure-line *Yala* paddies were used in these tests. The results may be seen in Tables I and II and in Text figs. 2 and 3. Unfortunately the *Yala* paddies were attacked by paddy moth, the unsmoked Hk-13 particularly so, and the germination percentages of this variety, especially after the 56th day are not reliable. There is sufficient evidence, however, to draw the following conclusions from these tests:—

1. The resting period in *Maha* (long-aged) paddies is about two and a half months, whereas with *Yala* (short-aged) paddies, if harvested when dead ripe, there is very little, if any, resting period. It is possible that certain *Yala* paddies do have a short resting period.
2. Smoking increases the germination of both *Maha* and *Yala* paddies. In the second month after harvest smoking increases the germination of *Maha* paddies from 10% to 30%. By the

middle of the third month the effects of smoking are almost negligible. *Yala* paddies so quickly attain their maximum viability that smoking is necessary only if the seed is to be sown immediately after harvest, say within one month.

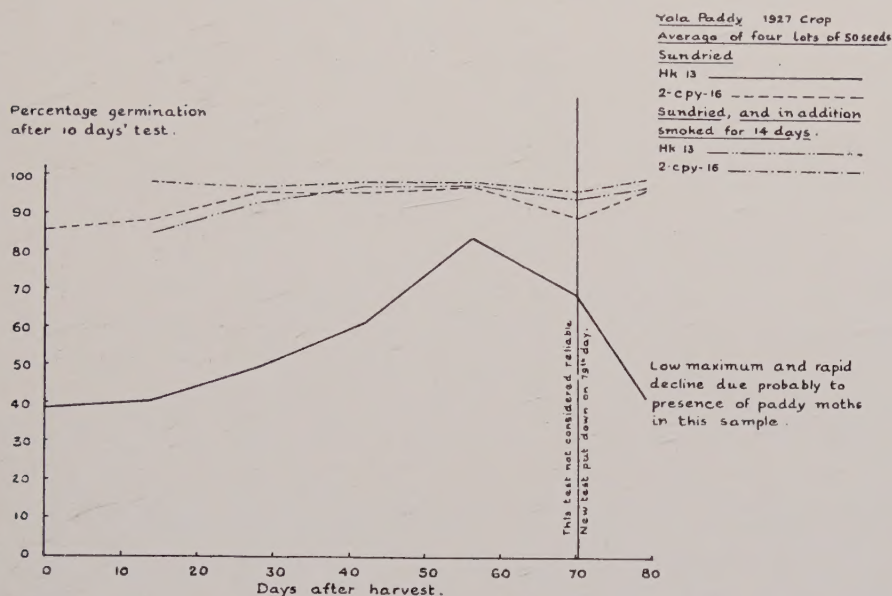


Fig. 3.—*Yala* Paddy seed. Age and Viability
Mitra and Gangully, (*loc. cit.*), found that in Assam the resting period for *sail* (long-aged ?) paddy was from three to four months and for *aus* (short-aged ?) paddy less than two months.

TABLE I
Maha Paddy Seed : Age and Viability

Days after Harvest	Percent Germination after 10 days			
	Unsmoked Seed		Smoked Seed	
	P-9	i-5	P-9	i-5
2	0.5	—	0.5	—
12	—	—	0.25	—
22	0.5	0.5	0.5	1.5
32	25.0	22.5	52.5	37.0
42	42.0	32.5	74.0	49.5
53	76.0	36.5	78.0	57.0
59	83.0	77.0	88.0	81.5
69	71.0	51.5	88.0	55.0
79	94.0	91.5	98.0	96.0
90	89.5	90.5	97.5	94.0
100	98.0	91.5	96.5	94.5

TABLE II

Yala Paddy Seed : Age and Viability

Days after Harvest	Percent Germination after 10 days			
	Unsmoked Seed		Smoked Seed	
	Hk-13	2-CPY-16	Hk-13	2-CPY-16
0	39.5	86.5	—	—
14	42.0	90.0	86.5	100.0
28	51.0	97.0	95.0	99.0
42	62.5	97.0	98.0	100.0
56	85.0	98.5	99.0	99.0
70	70.0	90.5	96.0	97.0
79	42.5	97.0	97.5	100.0

AGE OF SEED AND RAPIDITY OF GERMINATION

Maha and *Yala* seed of varying ages was tested to determine the effect of age on the rapidity of germination. The results of the tests may be seen in Table III and in Text fig. 4. The following conclusions have been drawn :—

Seeds germinated
each day as percentages
of total germinated.

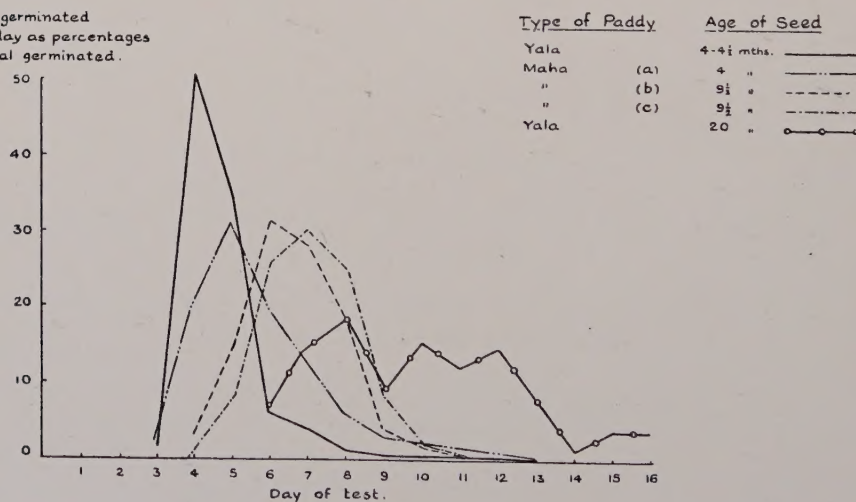


Fig. 4.—Paddy seed. Age and Rapidity of Germination

- (1) Comparatively new *Yala* seed almost completes its germination by the sixth day ; with similarly aged *Maha* seed germination is almost completed by the eighth day. Over 85% of four months old *Yala* seed has germinated by the fifth day and 70% of four months old *Maha* seed by the sixth day. If seeds

TABLE III
Paddy Seed : Age and Rapidity of Germination

Paddy	Months after harvest	Days after commencement of test and number of seeds germinated																No. of seeds tested	% ger- mina- tion
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16		
Yala	4½-5	—	—	50	1,722 51%	1,136 34%	211 6%	144 4%	43 1%	18 0.5%	17 0.5%	15 0.5%	4 0.1%	1	—	—	—	3,500	96
Maha	(a) 4	—	—	49	481 20%	755 30.5%	502 20%	320 13.5%	144 6%	80 3%	49 2%	35 1.5%	26 1.0%	14	—	—	—	3,200	76.7
	(b) 9½	—	—	—	41 3%	194 14%	417 31%	382 28%	250 18%	51 4%	18 1.5%	6 0.5%	—	—	—	—	—	1,400	97.3
	(c) 9½	—	—	—	19 1%	104 8%	347 25.5%	411 30%	330 25%	104 8%	27 2%	11 0.5%	—	—	—	—	—	1,400	96.7
Yala	20	—	—	—	—	—	7 7%	14 14%	18 18%	8 8%	15 15%	12 12%	14 14%	7 7%	1 1%	3 3%	3 3%	200	51

Note.—Percentage figures are approximate only and are in terms of total number of seeds germinated in each test.

were germinated in bulk and under pressure these amounts would probably be increased.

- (2) Old seed commences to germinate later, and continues to germinate longer, than new seed. Under village conditions much of this seed would rot before germination was half over.

The two *Maha* paddies labelled (b) and (c) had respectively standing water and no standing water in the porous dishes. It will be seen that the presence of standing water retarded germination by about one day. In the twenty months' old *Yala* paddy about 20% of the seeds developed plumules only. When placed on moist soil some of the more vigorous of those seeds put out adventitious roots, and grew. It is very doubtful, however, if such seeds would have withstood field conditions so they have not been included in the number of germinated seeds.

THE EFFECT OF GLUME COLOUR ON GERMINATION

To test this point twenty pure-line paddies were chosen, ten whose glume colour varied from light to medium straw and ten with glumes of

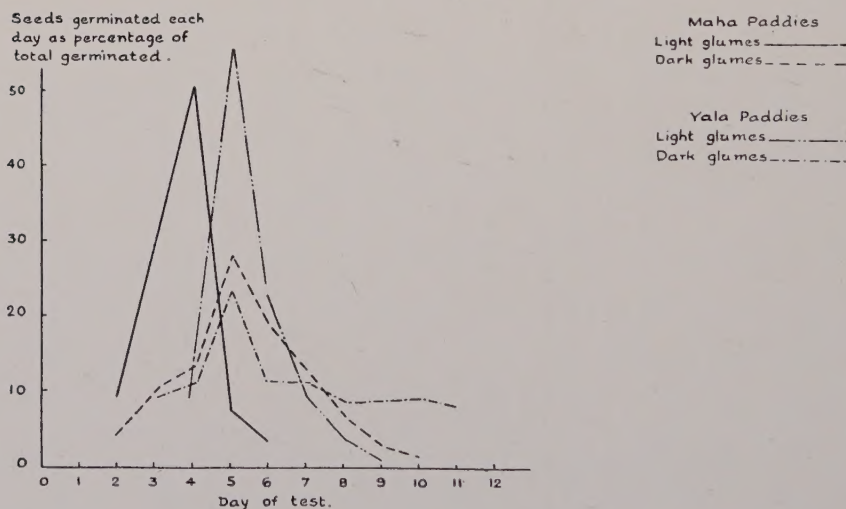


Fig. 5—Effect of Glume Colour on Germination.

medium brown, dark brown and brownish-purple. In each class five were *Maha* and five *Yala* paddies. The germination results will be found in Table IV. and Text fig. 5. It should be noted that comparisons between *Maha* and *Yala* paddies are not possible from these results, as the ages and times of tests were different. The ages and time of test of all the *Yala* paddies were the same, as also were the ages and time of

TABLE IV

Colour of glume and rapidity of germination

Maha Lines

Light Glumes

Days after start of test

Pure Line	No. of seeds germinated on each day.										Totals
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th day
k-7	—	3	13	74	1	1	—	—	—	—	—
G-19	—	7	36	28	12	5	2	—	—	—	—
i-10	—	18	46	27	2	2	—	—	—	—	—
P-5	—	3	11	23	9	6	1	—	—	—	—
a-12	—	7	20	53	6	1	—	—	—	—	—
Total	—	38	126	205	30	15	3	—	—	—	417
Rough % of total germination	—	9	30	50	7	3	—	—	—	—	83.4

*Dark Glumes**(dark brown)*

R-11	—	—	—	11	20	11	4	1	—	—	—
W-15	—	—	—	5	35	19	9	1	1	—	—
W-11	—	—	—	1	23	26	11	6	3	2	—
B-11	—	—	—	—	5	6	21	18	9	3	—
P-1	—	14	33	26	12	2	1	—	—	—	—
Total	—	14	33	43	95	64	46	26	13	5	339
Rough % of total germination	—	4	10	13	28	19	13	7	3	1	67.8

Yala Lines

Light Glumes

Days after start of test

Pure Line	No. of seeds germinated on each day.										Totals
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th day
Bf-20	—	—	—	20	47	16	9	1	1	—	—
Da-16	—	—	—	9	32	26	16	8	1	—	—
Da-27	—	—	—	3	55	28	8	2	—	—	—
Hj-14	—	—	—	6	67	17	6	2	1	—	—
Hm-2	—	—	—	6	55	23	1	1	2	1	—
Total	—	—	—	44	256	110	40	14	4	1	469
Rough % of total germination	—	—	—	9	55	23	9	3	1	—	93.8

Dark Glumes

Days after start of test

Pure Line	No. of seeds germinated on each day.										Totals
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th day
De-7	—	—	—	—	3	5	—	7	13	13	11
De-18	—	—	—	—	5	8	14	10	7	4	8
Hk-13	—	—	—	—	2	6	10	10	12	12	9
Hn-15	—	—	31	36	31	2	—	—	—	—	—
Hm-24	—	—	1	5	44	19	19	4	2	2	—
Total	—	—	32	41	85	40	43	31	34	31	28
Rough % of total germination	—	—	9	11	23	11	11	9	9	9	8
											73

test of the *Maha* paddies. The following conclusions appear to be warrantable from an examination of these tests:—

- (1) In general light-glumed paddies germinate sooner and complete their germination in less time than dark-glumed paddies.
- (2) The total germination of dark-glumed is less than of light-glumed paddies.¹

It will be noticed, however, that one dark-glumed *Maha* paddy (P-1) and one dark-glumed *Yala* paddy (Hn-15) completed germinating rapidly. It is possible, perhaps, that there is a tendency to harvest dark-glumed paddies on the immature side owing to the greater difficulty in such paddies in judging maturity by observation. It is hoped to investigate this point later.

SUMMARY

1. A technique for conducting germination tests with rice is described and shown to be efficient under Ceylon conditions.
2. The resting period for *Maha* paddies is found to be about two and a half months. *Yala* paddies, if harvested dead ripe, have little or no resting period.
3. "Smoking" the seed shortens the resting period.
4. New seed commences to germinate sooner and completes germination quicker than old seed. Comparatively new *Yala* seed is almost completely germinated in six days and *Maha* seed in eight days.
5. Light-glumed seeds germinate more rapidly than dark-glumed seeds.

1. Since this paper went to press the attention of the writer has been drawn to the effect of testa colour on germination. It has not yet been possible to ascertain this in Ceylon as among the long-aged paddies all the really light-glumed ones have white testas and all the dark-glumed ones red testas. In short-aged paddies, on the other hand, rice with a white testa have not yet been seen by the writer either in the light or dark-glumed groups.

I have to thank Mr. A. George Alwis of the Mycological Division for drawing the figures in this article.

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The Preliminary Testing of Pure-line Selections of Rice Part I¹

BY

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INTRODUCTION

The methods, reliability and statistical interpretation of plot tests of field crops have been studied by a large number of workers. As a result of their investigations a sufficiently accurate field plot technique has been evolved, but mainly from experiments on dry land crops. Batchelor and Reed (1918)² have summarised the work up to that date. At the present time there is an increasing tendency to use "Student's" method (1911), "Student's" method, which in the great majority of experiments materially reduces the standard deviation of the yields, was first used in field trials by Beaven (1922). Faulkner (1923) in India and Collison and Harlan (1923) in the United States also used this method; and the writer in Burma (1924) used "Student's" method with irrigated rice.

Whatever method of interpreting results is used, the investigator of the relative yielding powers of new selections is faced by two difficulties :—(1) The restricted amounts of seed available.

(2) The large number of selections to be tested.

Small supplies of seed mean that to have a reasonable number of replications (without which standard errors cannot be reduced to workable limits) plots must be very small. The large number of selections to be tested takes up a large area of land and a large amount of time. The sooner the number of selections of any variety is reduced to four or five the better. The problem is, therefore, to discover a suitable technique which has for its basis the utilisation of results from small plots, and by the use of which early discarding of all but the best few

1. Part I of this paper has already been published in the *Tropical Agriculturist* for November, 1926. Part II is published here for the first time. As this is a continuation of the investigations described in Part I it has been considered advisable to reprint that part here in order to facilitate reference.

2. A list of references will be found at the end of this paper

selections can be made with reasonable certainty that potential good selections have not been overlooked.

Small plots of three or five rows from 15 to 20 ft. long (the so-called rod-row plots) have been used in the United States for the preliminary testing of cereals, see Stadler (1921), and it was decided to determine the efficacy of such plots for testing rice selections. Parnell (1919) in Madras had previously tried two-row plots of 50 plants, but these were a failure owing to an exceptionally bad attack of crabs.

This paper is an account of the results obtained from three-row plots with standard errors determined by "Student's" method. Yields of plots were worked out to yields per hundred plants and the standard errors calculated by the formula given by Engledow and Udny Yule (1926).

MATERIAL USED IN THE INVESTIGATION

This consisted of 16 pure-line selections of the Ceylon rice *Sudu hinati* and 20 selections of the Ceylon rice *Kalu hinati*. The *Sudu hinati* selections are labelled 1 CPY and the *Kalu hinati* selections 2 CPY. The selections were in their second year after isolation and about five or six ozs. of seed were available of each selection. The number of selections of one variety which can usefully be dealt with in preliminary trials will be mentioned later under the heading "A consideration of the results."

FIELD TECHNIQUE

The plots used were three-row plots 14.5 ft. long. The distance between the outside rows of adjacent plots was 4 feet. This distance allowed of easy examination of the plots, rendered harvesting easier where there was lodging and tended to reduce the possibility of cross pollination. Rows were 6 ins. apart and plants 6 ins. apart in the rows. There were thus 90 plants per plot. Each variety was put down separately. The selections of each variety were planted consecutively and each selection was replicated ten times which was as many times as the available seed allowed.

The plots were transplanted, and one healthy seedling was planted in each place, not two or three as is the local practice. The nurseries were laid down in one field and about five ozs. of seed of each selection were sown in a nursery 5ft. by 5ft. Transplanting took place a month after sowing. In accordance with the local custom germinated seed was sown in the nurseries. Plots were kept 3ft. away from the bunds of the fields as it was found in Burma that proximity to bunds increases the yield. Weeding both in the plots and the interspaces was

carried out by hand whenever necessary. Land crabs are a more or less serious pest of rice in the East during the first week or so after transplanting. Wherever possible in these trials crabs were collected by boys and destroyed. One of the chief pests of rice in Ceylon is the Paddy Fly (*Leptocoris varicornis*) which attacks the plant when the grain is in the milk stage and by sucking the immature grains prevents their development. During the milk stage of the grain boys were employed continually in netting the "flies."

Between two and three months after transplanting the number of plants per plot was recorded. The plants were continually submerged from a week after transplanting until the grains entered the milk stage. Threshing was carried out by hand, and the grain was weighed after being sun-dried to constant weight.

THE STATISTICAL TREATMENT OF THE RESULTS

At the outset of the investigation it was intended to treat the results by "Student's" method (by comparing a selection of pairs of plots) and using "Student's" tables.¹ This would have meant that standard deviations would have been calculated from a sample of ten. Engledow and Yule state (*op. cit.* p. 124). "But even if as many as eighteen or twenty plots are given to each variety, this is a small number of observations on which to base a standard deviation, and little confidence can be placed on the differences between the rather diverse standard deviations that will be obtained from different pairs of varieties." The point to emphasize is the unreliability of standard deviations obtained by the use of small samples. After the publication of Engledow and Yule's paper it was decided to use their method of considering all possible pairs of varieties and thus ensure having a large sample. A brief method of calculating the standard deviation for all possible pairs of varieties has lately been evolved by "Student" (*Biometrika*, XV), with the aid of R. A. Fisher.

The formula as slightly modified by Engledow and Yule, and which has been used in this paper is as follows:—

$$\sigma_d^2 = \frac{2m}{m-1} (\sigma_v^2 - \sigma_p^2)$$

where σ_d^2 = mean variance² of the differences between comparable plots

1. *Biometrika*, XI, p 416.

2. Variance=square of the standard deviation (R.A. Fisher)

σ_v^2 = mean variance of yield for a variety round its now mean

σ_p = standard deviation of means for plots of the same number. In these results plots=fields.

and m = number of varieties

The standard deviation of the difference, therefore, is :—

$$\epsilon_d = \frac{\sigma_d}{\sqrt{n}}$$

where n is the number of pairs of plots from which d is found.

Results have been worked out in terms of standard error. "Statement of the probable error in modern work is an unmitigated nuisance, and the investigator is recommended to confine himself to the standard error and accustom himself to thinking in terms of it." (Engledow and Yule, *op. cit.*). Ten replications of the selections of each variety were put down, but in a few of the replications all the selections were not in the same banded field, *i.e.* 2 CPY 1 to 10 might have been in one field and 11 to 18 in another. Such replications have been discarded and the results given are from replications which were complete within one banded field. One of the fields contained as many as three replications of the complete series of selections. In future work all replications will be complete in one field, but at the time this experiment was started the writer had not seen Engledow and Yule's paper.

TABLE I
Yield of grain (in lbs. per 100 plants) from rod-row plots of 2 CPY.

Field No.	Pure Line																	Mean
	2 CPY																	
	1	2	3	4	6	7	8	9	10	11	12	13	15	16	17	18		
11 (b)	3.05	3.67	3.51	2.48	3.39	3.66	4.21	2.56	2.51	2.85	2.91	3.22	5.46	3.19	3.08	2.52	3.27	
11 (c)	1.92	1.80	1.62	1.91	2.13	3.48	3.17	2.88	2.75	3.46	4.11	2.34	3.91	3.33	3.35	3.67	2.86	
12 (d)	2.86	2.15	2.48	2.79	2.45	2.77	2.92	2.18	2.58	2.37	1.71	2.68	3.04	2.61	3.68	2.87	2.63	
12 (e)	1.94	3.25	2.35	2.14	2.64	2.99	3.07	2.95	3.49	3.84	3.28	3.31	3.26	2.75	3.54	2.31	2.94	
12 (f)	2.99	2.75	3.44	1.83	2.37	2.97	2.85	2.44	2.74	4.69	3.56	2.88	3.27	2.86	3.16	3.43	2.95	
13 (g)	2.64	2.37	3.25	2.55	3.43	3.59	2.23	2.93	1.48	3.85	2.66	2.72	3.33	2.29	3.79	2.26	2.84	
13 (h)	2.17	3.06	3.22	2.51	3.80	3.31	2.42	2.09	3.24	2.96	2.87	3.58	2.87	2.59	3.92	2.81	2.96	
13 (i)	3.14	2.97	2.71	4.11	2.36	3.08	2.60	2.06	3.09	3.62	2.71	3.35	3.09	2.09	3.27	3.03	2.95	
Mean	2.59	2.75	2.82	2.54	2.82	3.23	2.93	2.51	2.73	3.45	2.98	3.01	3.53	2.71	3.47	2.74	2.93	

TABLE II

Deviations of the yields in Table I from the means of the respective varieties

Field No.	Pure-line, and " rough mean "										2 CPY																					
	1		2		3		4		6		7		8		9		10		11		12		13		15		16		17		18	
	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—	+	—
11 (b)	0.46		0.92		0.69			0.06	0.57		0.43		1.28		0.05		0.22		0.60		0.07	0.21		1.93		0.48			0.39		0.22	
11 (c)		0.67		0.95		1.20		0.63		0.69	0.25		0.24		0.37		0.02		0.01		1.13		0.67	0.38		0.62			0.12	0.93		
12 (d)	0.27			0.60		0.34	0.25			0.37		0.46		0.01		0.33		0.15		1.08		1.27		0.33		0.49		0.10	0.21		0.13	
12 (e)		0.65	0.50			0.47		0.40		0.18		0.24	0.14		0.44		0.76		0.39		0.30		0.30			0.27	0.04		0.07		0.43	
12 (f)	0.40				0.62			0.71		0.45		0.26		0.08		0.07	0.01		1.24		0.58		0.13		0.26	0.15			0.31		0.31	
13 (g)	0.05			0.38	0.43		0.01		0.61		0.36			0.70	0.42		1.25	0.40			0.32		0.29		0.20		0.42	0.32			0.48	
13 (h)		0.42	0.31		0.40			0.03	0.98		0.08			0.51		0.42	0.51		0.49		0.11	0.57			0.66		0.12	0.45		0.07		
13 (i)	0.55		0.22			0.11	1.57			0.46		0.15		0.33		0.45	0.36		0.17			0.27	0.34			0.44		0.62		0.20	0.29	
Check Totals	1.73	1.74	1.95	1.93	2.14	2.12	1.83	1.83	2.16	2.15	1.12	1.11	1.66	1.63	1.28	1.27	1.66	1.62	2.21	2.17	2.01	2.04	1.42	1.42	2.31	2.32	1.29	1.26	1.05	1.02	1.42	1.44

TABLE III

Squares of the deviations of Table II for calculation of σ_v

[illegible]

TABLE IV

Calculation of σ_p , the standard deviation of the fields.

Field No.	Data (Table I)	Deviations		Squares
11 (b)	3.27	+	—	0.1156
11 (c)	2.86	0.34	0.07	0.0049
12 (d)	2.63		0.30	0.0900
12 (e)	2.94	0.01		0.0001
12 (f)	2.95	0.02		0.0004
13 (g)	2.84		0.09	0.0081
13 (h)	2.96	0.03		0.0009
13 (i)	2.95	0.02		0.0004
	2.93	0.42	0.46	0.2204

STATEMENT OF RESULTS

Working with the yields of the plots in terms of yields per 100 plants the results obtained are as follows :—

	1 CPY	2 CPY
Mean of all plots	2.61 lbs.	2.93 lbs.
Standard deviation of the <i>difference</i> (Engeladow and Yule's formula)	0.67 "	0.75 "
Standard error of average difference :		
1 CPY = 6 replications	0.27 "	—
2 CPY = 8 replications	—	0.265 "
Standard error of difference, ordinary method	0.36 "	0.27 "

That is, the average yield of 1 CPY selections is 2.61 lbs. with a standard error of 0.27 lbs. By the ordinary method the standard error is 0.36 lbs., a considerably higher figure due to the less uniformity between the different fields used for the 1 CPY series. The 2 CPY selections show a standard error almost the same by both methods, which is due to the greater uniformity of the fields used in the 2 CPY series. The variance of these fields was 0.0275 only, whereas the variance of the fields used for the 1 CPY series was 0.1924. Naturally, the reduction of the standard error by "Student's" method is greater when fields are less uniform in fertility. To save space the results of the variety 2 CPY only are given in detail.

Table I shows the yield of grain in lbs. per 100 plants of each plot, together with the means of each selection and the means of each series.

Table II gives the deviations of each plot from the mean of the respective selections. Table III gives the squares of the above.

$$\begin{aligned}\sigma_v^2 &= \frac{37.3935}{128} \\ &= .2916 \\ \sigma_v &= 0.54 \\ \epsilon_d &= \frac{0.54 \sqrt{2}}{\sqrt{8}}\end{aligned}$$

$= 0.27$ *i.e.* the standard error of the difference between two means without eliminating the field variance.

Table IV shows the calculations for σ_p —the standard deviations of the fields.

$$\begin{aligned}\sigma_p^2 &= \frac{0.2204}{8} \\ &= 0.0275\end{aligned}$$

Therefore, according to Engledow and Yule's formula

$$\begin{aligned}\sigma_d^2 &= \frac{2m}{m-1} (\sigma_v^2 - \sigma_p^2) \\ &= \frac{2 \times 16}{15} (0.2916 - 0.0275) \\ &= 0.564\end{aligned}$$

$$\text{and } \sigma_d = 0.75$$

The standard error of the mean difference between any pairs of plots is

$$\begin{aligned}\epsilon_d &= \frac{\sigma_d}{\sqrt{n}} \\ &= \frac{0.75}{\sqrt{8}} \\ &= 0.265\end{aligned}$$

THE LEGITIMACY OF BASING CALCULATIONS ON YIELD PER
HUNDRED PLANTS

One method of working out the standard deviations of these results would be to use the actual grain weights per rod-row plot. It was found, however, that within two or three months after transplanting the full number of 90 plants per plot was not growing. In one plot the number was as low as 61, in some plots there were 89 plants and in one plot 90. Plants were destroyed by crabs in the early stages, field mice in the later, and a certain number did not survive after transplanting. It would appear to be unfair to compare the yield of 61 plants with that of 89 plants: accordingly, yield per 100 plants was taken, but it was not forgotten that effective tillering might be greater in the plots with fewer plants. Effective tillering means tillers bearing mature ear-heads. A certain number of late tillers bear immature ear-heads. These have no effect on the yield (in Ceylon they are actually harmful as they extend the period during which the Paddy Fly has available grain in the milk stage on which it can feed).

Greater space in the plots, with fewer number of plants, if followed by more effective tillering, and no corresponding decrease in the size of ear-heads would give a yield per 100 plants higher than the average. Has this happened? It was considered necessary, therefore, to determine the legitimacy of using yields per 100 plants by working out the correlation coefficient between number of plants per plot and deviation from the means of the respective selections. Table V is the correlation table for these two factors for the selections of variety 2 CPY. The coefficient of correlation works out to -0.264 ± 0.055 . There is, therefore, negligible correlation between the two factors and the use of yields per 100 plants would, therefore, appear legitimate. The coefficient of correlation is more than four times the probable error; moreover, it is very low, so notwithstanding the fact that rather large class intervals were used, it can definitely be stated that there is no correlation. The 1 CPY selections give a coefficient of correlation of -0.057 ± 0.06 . The fact that in these plots a smaller number of plants per plot did not result in a higher yield per plant has two possible explanations:

- (i) the gaps in the plots may have occurred too late in the growing period of the plant to have influenced effective tillering, and
- (ii) the four-foot space between plots may have resulted in most of the plants in the plots having the maximum number of tillers.

TABLE V
Showing correlation between yield of grain per 100 plants and number of plants per plot

No. of plants per plot	Differences from mean of respective selection															Totals
	-1.6, 1.4: -1.3, 1.1: -1.0, -0.8: -0.7, -0.5: -0.4, -0.2: -0.1, 0.1: 0.2, 0.4: 0.5, 0.7: 0.8, 1.0: 1.1, 1.3: 1.4, 1.6: 1.7, 1.9															
90-92							1									1
87-89	1			1	3		6		1							12
84-86		1		1	7		10		4							29
81-83	1	1		4	10		3		8		3					32
78-80				3	6		3		3		2		3			15
75-77	1			2	3		6		3		3					18
72-74					3				2		2					8
69-71				1	1				2		2		1			5
66-68					1		1		3		3					5
63-65					1				1							2
60-62															1	1
Totals	—	3	2	12	35		30		27		11	3	3	1	1	198

Border effect is discussed in the next paragraph. Where the inner three rows of five-row plots are used in preliminary tests it may be found that the number of harvested plants per three inner rows is correlated with the yield per plant, as in this method there is no large border to encourage maximum tillering. When inner rows are used this point must be kept in mind and the results must be critically examined before deciding whether to use yields per hundred plants or actual yields per plot.

COMPETITION AND BORDER EFFECT

To facilitate the study of the different selections and to reduce the chance of natural crossing spaces four feet wide were left between the plots. There was, therefore, no chance of competition, but there must have been a certain border effect because of these spaces. Ramiah (1924) has shown that there is a definite border effect with rice; he has also shown that "the Probable Error.....is found to be very nearly the same both for the yields of the seven middle rows only and for all the nine rows." Border effect is not, primarily, concerned with the object of this paper which is to find out the magnitude of the standard deviations in three-row plots with rice, when their standard deviations are determined by Engledow and Yule's formula.

It is not at all sure that border effect with transplanted rice is going materially to influence the *comparative* yields of different selections so long as the conditions of growth for each selection are the same. Ramiah's results (*op. cit.*) would not indicate very much effect on comparative yields. He was dealing with nine-row plots. Three-row plots would show a relatively greater border effect. An experiment has now been laid down by the writer to determine the effect of a border on the comparative yields of different rice selections in rod-row plots and also to compare yields from rod-row plots with yields of field plots as eventually it is yield under field conditions which matters. If border effect proves to be important it will be a simple matter to put down five-row plots and to harvest the middle three only. In the early stages of a selection when seed is limited, this would mean, unfortunately, decreasing the number of replications.

If border effect is found to be important and if the inner three rows of five-row plots are utilised for determining the yields it will be necessary to re-examine the legitimacy of using yields per 100 plants under such conditions. With border effect having full play—as it does in the three-row plots—a slight decrease in the number of plants per plot would obviously tend to have little effect on the yield per plant. A decrease in the number of plants in the inner three rows of a five-row

plot *may* exercise some effect on the yield per plant. The problem will be kept in mind when dealing with the effect of borders.

SEASONAL EFFECT

The seasonal effect on the relative performance of rice selections is very probably not so important as with crops which rely entirely on rainfall *in situ*. In most countries rice is irrigated to a greater or lesser extent and seldom relies entirely on direct rainfall. In Ceylon (as elsewhere) the rice cultivator is particularly ingenious in utilising all possible supplies of water. It is hoped within the next few years to determine the magnitude of the seasonal errors with rice in Ceylon.

TABLE VI

Showing yields of the selections of the two varieties in order of merit

1 CPY $\epsilon_d=0.27$			2 CPY $\epsilon_d=0.265$		
Selection	Av. yd. per 100 plants	Difference	Selection	Av. yd. per 100 plants	Difference
	<i>lbs.</i>			<i>lbs.</i>	
19	3.99	—	15	3.53	—
16	3.32	0.67	17	3.47	0.06
17	3.29	0.03	11	3.45	0.02
18	3.23	0.06	7	3.23	0.22
5	3.12	0.11	13	3.01	0.22
3	2.83	0.29	12	2.98	0.03
6	2.78	0.05	8	2.93	0.05
15	2.73	0.05	6 & 3	2.82	0.11
20	2.68	0.05	2	2.75	0.07
13	2.60	0.08	18	2.74	0.01
2	2.56	0.04	10	2.73	0.01
7	2.49	0.07	16	2.71	0.02
21	2.38	0.11	1	2.59	0.12
4	2.30	0.08	4	2.54	0.05
19	2.29	0.01	9	2.51	0.03
22	2.23	0.06			
14	2.11	0.12			
8	1.97	0.14			
12	1.85	0.12			
1	1.60	0.25			

A CONSIDERATION OF THE RESULTS

In Table VI the yields of the selections of the two varieties are shown in order of merit together with successive differences. Engledow and Yule state that a difference cannot be very significant unless it is three times the standard error. Applying this criterion we find that in the 1 CPY selections 19 can be stated to be superior in yield to 5 and down but not to 16, 17 and 18. In the 1 CPY selections 15 is

superior to 18 and down but not to the others. It could not, for instance, be stated that 2 CPY 16 is undoubtedly superior to 6 or even to 2 if we insist on a difference of three times the standard deviation. We might be satisfied, say, with a difference of 2.15 times the s.d. which would give odds of 30 to 1. Then 1 CPY 19¹ is superior to all in that series and 2 CPY 15 superior to 2 CPY 8 and down.

The problem in rice selection work is to make early discards—the more selections under trial the more space and labour are wanted. Does the method described enable us to discard with certainty sufficient of the poor yielders? Employing odds of 30–1 (*i.e.* 2.15 times the s.d.) the method, even with only 6 and 8 replications, is satisfactory. Increasing the number of replications to ten or twelve would make it possible to insist on differences of three times the s.d. and the writer recommends this number of replications whenever possible in preliminary trials. In later trials when more seed is available selections can be replicated sufficiently to detect accurately small differences. But the technique described makes it fairly certain that the best selection of any series is within the first five or six.

No arbitrary figure can be laid down as to the original number of selections which ought to be made from the mixed population. Space and labour must be considered. The writer suggests an initial selection of 50 lines grown the first season on the ‘ear to row’ method and reduced after harvest to about 20 lines by means, *inter alia*, of observation and a consideration of grain weight per plant. In the second season these remaining lines would be put down for preliminary tests on the method described in this paper. No practical method will make absolutely sure of finding the best selection; there should, however, be little difficulty in finding a selection greatly superior to the mixed population if a correct technique is adopted.

SUMMARY

1. This paper describes a method for the preliminary testing of rice selections.
2. Three-row plots 14.5 ft. long containing 90 plants, evenly spaced, were used.

1. A further examination of the results of the 1 CPY selections brings out the fact that the average number of plants per plot in 1 CPY 19 is 55 only, whereas the average for all the plots is 78. It would appear, therefore, that some special, unexpected and hitherto unnoticed factor has affected the growth of this selection, *e.g.* disease in the nurseries. In such an exceptional case it would be safer not to place too much reliance on the calculated results. In the future course of this work 1 CPY 19 will again be tested against the other top yielders. Tabulation of the results of preliminary tests would advisably be in such a form as would easily make evident any extreme variation from the normal of the average number of plants in the plots of any selection. Where nurseries are all grown in one field (as in this investigation) such extreme variation should be very rare.

3. Plot yields were worked out to yield per 100 plants and an attempt has been made to show the legitimacy of this procedure.
4. Standard deviations of plot yields have been determined from all possible pairs of plots by means of the brief method evolved by "Student" and R. A. Fisher, using the modified formula of Engledow and Yule.
5. The use of the above technique is shown to be satisfactory. Ten to twelve replications of each selection tested are recommended.

I am indebted to Mr. K. D. S. S. Nanayakkara for careful supervision of the field work and to Mr. L. Abeyesundera for assistance in working out the results.

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The Preliminary Testing of Pure-line Selections of Rice—(Contd.)

Part II

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WITH ONE PLATE

The first part of this paper described the use of the so-called rod-row plot in the preliminary testing of rice selections at an early stage in their history when seed was available only in small quantities. The experimental errors of ten to twelve replicated plots were sufficiently low to render the use of these plots feasible in the first weeding out of the lower yielders at a time when comparatively large differences in the yields of selections are to be expected. The conclusions reached as to border effect and the employment of yields per 100 plants instead of total yields will be mentioned later in this paper. The investigation of this subject has been continued for the past two seasons. The methods of statistical examination of results and of plot arrangement have been altered. This paper describes these alterations and gives an account of the information obtained on border effect ; on the legitimacy of using yields per 100 plants ; on the value of different types of plots, and on the magnitude of the experimental errors which may be expected from their use.

THE STATISTICAL EXAMINATION OF RESULTS

In the first part of this paper the calculation of experimental errors was made by Engledow and Yule's (1)¹ modification of the formula devised by "Student" with the aid of R. A. Fisher. It has been pointed out by Fisher (4) that this modification, in estimating the residual errors of a replicated experiment has produced "in some cases a serious under-

1. Numbers in brackets refer to literature cited, a list of which will be found at the end of this paper.

estimate." The methods described by Fisher (2) pp. 176-232 are now employed. Table I illustrates this method used in calculating the experimental error of a varietal trial with ten varieties of rice.

TABLE I (a)

Yield of Grain (in hundredths of a lb. per 100 plants) of inner 3 rows of 1 and 2 CPY Selections, Yala 1927.

Numbers in brackets show the No. of plants
Randomized Blocks.

<i>Selection</i>	<i>a</i>	<i>b</i>	<i>c</i>	<i>d</i>	<i>Block</i> <i>e</i>	<i>f</i>	<i>g</i>	<i>h</i>	<i>i</i>	<i>j</i>	<i>Mean</i>
(1) 1 CPY 5	255 (85)	214 (86)	244 (84)	360 (85)	331 (88)	368 (84)	354 (87)	317 (81)	264 (84)	330 (89)	304 (85)
(2) 1 CPY 15	250 (89)	335 (72)	244 (87)	322 (83)	340 (81)	256 (87)	298 (84)	372 (79)	310 (85)	257 (82)	298 (83)
(3) 1 CPY 16	277 (87)	188 (78)	325 (83)	295 (86)	295 (83)	280 (87)	287 (86)	310 (82)	355 (82)	306 (76)	292 (83)
(4) 1 CPY 3	234 (86)	261 (85)	216 (85)	394 (82)	260 (83)	308 (85)	272 (87)	328 (78)	331 (83)	241 (82)	284 (84)
(5) 1 CPY 19	247 (80)	282 (74)	188 (77)	340 (79)	285 (82)	275 (75)	325 (83)	251 (82)	313 (81)	274 (77)	278 (79)
(6) 1 CPY 17	238 (89)	204 (90)	143 (84)	229 (86)	323 (86)	267 (83)	282 (84)	353 (89)	275 (85)	249 (85)	256 (86)
(7) Hinati	225 (79)	195 (84)	129 (71)	243 (81)	308 (76)	275 (83)	201 (83)	322 (82)	329 (79)	260 (65)	249 (78)
(8) 1 CPY 6	195 (82)	199 (85)	191 (87)	275 (79)	368 (68)	237 (79)	266 (77)	252 (75)	271 (72)	218 (83)	247 (79)
(9) 1 CPY 18	171 (88)	231 (88)	158 (90)	254 (85)	332 (79)	318 (84)	225 (84)	256 (87)	207 (88)	178 (85)	233 (86)
(10) 2 CPY 16	190 (84)	194 (82)	179 (73)	219 (80)	209 (80)	253 (79)	242 (76)	231 (83)	121 (89)	225 (86)	206 (81)
									Mean		264.7

TABLE I (b)
Deviations from working mean, 100

[illegible]

(c) Squares

Sum of Squares of above deviations = 3049255

Sum of Squares, Total = 3049255 — $(164 \cdot 79 \times 16479)$

= 3049255 — 2715574 · 41

= 333680 · 59

Sum of Squares, Local Differences

1/10 of $(1282^2 + 1303^2 + 1017^2 + 1931^2 + 2051^2 + 1837^2 + 1752^2 + 1992^2 + 1776^2 + 1538^2)$ — $(164 \cdot 79 \times 16479) = 2824274 \cdot 1 - 2715574 \cdot 41$

= 108699 · 69

Sum of Squares, Varieties

1/10 of $(2037^2 + 1984^2 + 1918^2 + 1845^2 + 1780^2 + 1563^2 + 1487^2 + 1472^2 + 1330^2 + 1063^2)$ — $(164 \cdot 79 \times 16479) = 2805656 \cdot 5 - 2715574 \cdot 41$

= 90082 · 09

Sum of Squares, Remainder = Total — (Blocks and Varieties)

= 333680 · 59 — 198781 · 78

= 134898 · 81

(d)

Variance due to	Degrees of Freedom	Sum of Squares	Mean Square	S.D.	Log E
Local Differences	9	108699 · 69			
Varieties	9	90082 · 09	10009 · 12	100 · 04	4 · 6052
Experimental Error	81	134898 · 81	1665 · 42	40 · 81	3 · 7089
Total	99	333,680 · 59		Difference =	0 · 8963

Variance = 1665 · 42

Variance of mean of 10 Plots = $\frac{166 \cdot 542}{10}$ S.E. = $\sqrt{166 \cdot 542}$

= 12 · 9

S.E. of difference of means = $12 \cdot 9 \times \sqrt{2}$

= 18 · 24

= 6 · 89%

 $z = 0 \cdot 8963$

As will be seen, the different variances due to "variety" and to "local differences," i.e., the differences between the blocks of each replication due to soil heterogeneity, are determined separately and are subtracted from the total variance, leaving the variance directly due to the errors of the experiment. The variances due to "variety" and to the experimental error (the residual variance) will be found in column 4, Table I (d). If the variance due to "variety" is significantly greater than the residual variance the experiment is accurate enough to differentiate between the more marked varietal differences. The test of significance of the difference of the two variances is known as the z test, (Fisher, (2), p. 192); z is equal to "half the difference of the *natural* logarithms of the estimates of the variance, or to the difference of the logarithms of the corresponding

standard deviations." In this example it is seen that z equals 0.8963. In this work odds of 20 to 1 that differences are not due to chance have been accepted as sufficient. This is a probability of .05, and results which do not give this probability are ignored. The different values of z for the different values of n_1 and n_2 for a probability of .05 are given by Fisher (2) in his Table VI. To return to the example quoted above, it is seen that z equals 0.8963. Inspection of the Table of z shows that for $n_1=8$ and $n_2=24$ $z = .4283$.

It is clear, therefore, without interpolating for the value of z for $n_1 = 9$ and $n_2 = 81$, then, that the variance due to variety is significantly greater than the residual variance. The yields of the varieties in this example may now be put down in order of merit and the significance of successive difference determined by means of the Table of t ⁽¹⁾—Fisher (2).

$$t = \frac{\text{mean difference between two varieties}}{\text{Standard error of the difference (S. E}_d\text{.)}}$$

and the table gives the values of t for the different values of n and for different probabilities. n is equal to the degrees of freedom for the experimental error. In this example $n = 81$ and the $S.E_d = 18.24$. Reference to the table of t will show that for $P = .05$ with n over 30, the value of t must be 2 or over. That is, the mean difference must equal or exceed twice its standard error. The following table shows the mean yields of the different selections in order of merit with successive differences,

TABLE II
Mean Yields of inner 3 rows of rod-row plots of 1 and 2 CPY Selections

<i>Selection</i>	<i>Mean Yield per 100 plants in 1/100 of a lb.</i>	<i>Difference</i>	
1 CPY 5	304	—	Standard error of difference = 18.24
1 CPY 15	298	6	
1 CPY 16	292	6	
1 CPY 3	284	8	Difference to be significant must exceed 18.24 $\times 2 = 36.48$
1 CPY 19	278	6	
1 CPY 17	256	22	
Hinati	249	7	
1 CPY 6	247	2	
1 CPY 18	233	14	
2 CPY 16	206	27	

(1) It has been pointed out to the writer by Dr. Fisher that the use of the t test furnishes little additional information, for when the z test is significant the more striking varietal differences may be relied on. The writer wishes to take this opportunity of thanking Dr. Fisher for his very kind help. Dr. Fisher has not seen this paper and any mistakes there may be in the application of the statistical methods are due to the writer.

Hinati may be taken as the control variety in this experiment. The yields of selections 1 CPY 16, 15 and 5 exceed the yield of *Hinati* by 36.48. From the point of view of yielding power, therefore, the remaining selections may be discarded. The experiment does not differentiate between the yielding powers of 1 CPY 5, 15 and 16. By the present method of calculating errors, the standard errors of the difference of the 1 and 2 CPY selections given in part I. of this paper have been raised respectively 1.32% and 0.70%. In both cases the z test shows significance.

A comparison of the 1927 results with those of 1926 is necessary at this point. After considering the results of the 1926 tests all the 2 CPY selections except 2 CPY 16 were discarded owing to the grains being awned. The eight top yielders of the 1 CPY selections were retained along with 2 CPY 16 for further testing. The comparison with the 1927 results shows that the low yield of 2 CPY 16 has been maintained. Unfortunately as no control variety of village paddy was included in the 1926 tests no direct comparison is possible. Turning to the 1 CPY selections it will be noticed that 1 CPY 19, which in 1926 yielded significantly more than the other 1 CPY selections, has now yielded significantly more than 1 CPY 18 only. Does this mean that the use of rod-row plots is unsatisfactory? It will be noticed that the footnote on p. 284 of the first part of this paper states that the number of plants per plot of the 1 CPY 19 selections was far below average and that "In such an exceptional case it would be safer not to place too much reliance on the calculated results." The further investigation of the legitimacy of using yields per 100 plants has shown that yields per 100 plants are not reliable if the number of plants per plot is much below average. This is dealt with in a later section. Apart from this there is no indication in the 1927 results that the previous year's results are unreliable. In 1926, 1 CPY 16 yielded 59 units more than 1 CPY 15, which was a significant figure with an S.E. of 27. The S.E. of those 1926 results worked out by the present method is 30.5 and the difference is not significant. It must be remembered, also, that the 1927 results, owing to the randomized arrangement of plots, are more reliable. On the whole there is no evidence in this comparison that the rod-row plot as a medium of testing large differences in yield is unreliable, *provided* that an average number of plants in each plot reaches maturity.

PLOT ARRANGEMENT

In laying down the first tests of rice selections by means of 3-row rod-row plots each replication occupied a more or less compact block, but one or two of the replications were not wholly in one banded field,

In working out the results of those tests those replications in which part were in one field and part in another were not used. It was thus possible to eliminate the variance due to "local differences" that is, the differences of fertility between different replications or blocks. The plots, however, within each block were laid down systematically and Fisher (3) p. 506 has pointed out that such a systematic arrangement does not permit of a valid estimation of the errors of the experiment. He says "One way of making sure that a valid estimate of error will be obtained is to arrange the plots deliberately at random so that no distinction can creep in between pairs of plots treated alike and pairs treated differently; in such a case an estimate of error, derived in the usual way from the variations of sets of plots treated alike, may be applied to test the significance of the observed difference between the averages of plots treated differently.....It is particularly to be noted that those methods of arrangement, at which experimenters have consciously aimed, and which reduce the real errors, will appear from their (falsely) estimated standard errors to be not more but less accurate than if a random arrangement had been applied; whereas if the experimenter is sufficiently unlucky, as must often be the case, to *increase* by his systematic arrangement the real errors, then the (falsely) estimated standard error will now be smaller, and will indicate that the experiment is not less but more accurate. Opinions will differ as to which event is, in the long run, the more unfortunate; it is evident that in both cases quite misleading conclusions will be drawn from the experiment."

The 1927 yields in Table I of the combined 1 and 2 CPY selections are from plots in "randomized blocks," each block containing one replication and being completely within one banded field. The position of each plot within the blocks was determined by drawing numbers out of a hat.

It has been shown by the writer (6) that in fields which are part of a properly devised irrigation scheme with both irrigation and drainage channels, the yields of plots adjacent and parallel to these channels are invariably much higher than other plots. Experience at the Experiment Station, Anuradhapura, where there is such an irrigation scheme, confirms this. It would appear advisable, therefore, to lay down plots as far as possible at right angles to the irrigation channels. An additional precaution would be to have the plot borders (which are harvested separately before the plot proper) made double the breadth whenever they run alongside any bund. Alternatively or in addition plots could be laid down with their borders not closer than four feet to the bund. Four feet is an arbitrary distance, and demands on space will have to

be considered. These precautions do not effect the method of laying down plots in randomized blocks.

ROD-ROW PLOTS AND BORDER EFFECT

A certain amount of data has now been collected on the effect of a border of unoccupied land on the yields of the outer rows of rod-row plots. The border of unoccupied land effectively prevents competition between varieties or selections and is useful in lessening the risk of cross-pollination between adjacent pure-lines. It has been found that the two outside rows of 5-row rod-row plots frequently yield as much as the three inner rows. Varieties which tiller well will probably utilise the border more efficiently than varieties which tiller poorly and thus cause a source of error, as under field conditions there is little border to make use of. The following table shows the 1927 yields of nine pure-line selections of *Hinati* expressed as percentages of the yield of village *Hinati*, both for the inner three rows and for all rows of 5-row rod-row plots.

TABLE III

Selection	Yield per 100 plants. Mean of 10 replications in randomized blocks.			
	Inner 3 rows	Order of Merit	All rows	Order of Merit
1 CPY 5	122	1	120	2
1 CPY 15	120	2	116	3
1 CPY 16	117	3	125	1
1 CPY 3	114	4	115	4
1 CPY 19	112	5	111	5
1 CPY 17	103	6	104	6
<i>Hinati</i>	100	7	100	7
1 CPY 6	99	8	96	8
1 CPY 18	93	9	93	9
2 CPY 16	83	10	79	10

In these selections the comparative effect of the border has been insignificant, due, perhaps, to the fact that nine of the pure-line selections are from the same variety and little difference in tillering capacity would normally be expected. A more elaborate experiment was laid down at the Experiment Station, Anuradhapura, during the *Yala* season of 1927. The objects were to determine—

- (i) Comparative differences in yield between two pure-lines grown (a) in field plots, (b) in rod-row plots with plants 6" apart each way, and (c) in rod-row plots with plants 12" apart each way.
- (ii) The effect of border in the two types of rod-row plots, and
- (iii) The effect of reducing well below normal the number of plants in rod-row plots. This part of the experiment will be dealt with in the following section.

Two pure-line selections were used for this experiment, Mb-14 a selection of *Murungan* and De-18, a selection of *Danahala*. Field plots of 1/117 acre were used and ten sandwiches of De-18 and Mb-14 were transplanted in one field. The relative positions of the two selections in each sandwich was at random and no space was left between plots. Owing to the greater yield of plots adjacent and parallel to the bunds, the sandwiches at either end of the field were not included in the results. Each replication of the rod-row plots was as follows :—

- (a) Mb-14 in 6" rod-rows
- (b) De-18 do
- (c) Mb-14 in 6" rod-rows but a number of plants removed later.
- (d) Mb-14 in 12" rod-rows
- (e) De-18 do
- (f) Mb-14 in 12" rod-rows but a number of plants removed later.

Twenty-nine replications were put down and in view of the complicated nature of the experiment and in order to simplify it as much as possible the relative positions of the plots in each replication were unchanged. It is unfortunate that the absence of random arrangement of plots is a source of error. Plots (c) and (f) are not concerned with the present discussion. Replications adjacent to the irrigation channel were again discarded leaving twenty replications available for working out the results. Plots with plants 12" apart both ways were laid down as the greater distance between plants was considered sufficient for maximum tillering. If so, there would be no border effect. The ordinary method of transplanting in the field and in field test plots is to plant bunches of 1-4 plants about 6" apart. Even if 12" rod-row plots eliminated border effect it was obviously necessary to compare the relative yields of selections grown in such plots with their yields grown in field plots where there is much less room for tillering. Table IV gives the results of the experiment, the yields of De-18 being expressed as percentages of the yields of Mb-14.

TABLE IV

The comparative differences between De-18 and Mb-14 obtained from different types of plots.

<i>Type of plot</i>	<i>Selection</i>		<i>S.E.</i> ¹ <i>d</i>	
	<i>De-18</i>	<i>Mb-14</i>		
	<i>Yields per 100 plants.</i>			
1/117 ac.	107.8	100	6.2%	(n=7)
6" rod-rows, inner 3 rows	100.7	100	7.3%	(n=19)
6" rod-rows, all rows	111.0	100	4.2%	(-do-)
12" rod-rows, inner 3 rows	135.0	100	6.9%	(-do-)
12" rod-rows, all rows	136.0	100	6.6%	(-do-)
	<i>Total Yields.</i>			
6" rod-rows, inner 3 rows	108.4	100	7.0%	(-do-)
6" rod-rows, all rows	118.0	100	4.5%	(-do-)
12" rod-rows, inner 3 rows	146.6	100	8.0%	(-do-)

The experimental errors are very large, but the results indicate that (i) Comparative yields from the inner three rows of rod-row plots are comparable with the yields from field plots. Within the limits of the experimental error with these types of plots both selections are approximately equal in yield.

(ii) The inclusion of the outside border rows of 6" rod-row plots affects the comparative yields.

(iii) Comparative yields from 12" rod-row plots may not be similar to those from field plots, and this precludes their adoption in varietal testing although there is no border effect with such plots.

As a result of this experiment the use of the inner three rows of 6" rod-row plots is recommended. Discarding the outer rows is, moreover, an additional precaution against natural cross-pollination.

THE LEGITIMACY OF USING YIELDS PER 100 PLANTS

In the first part of this paper it was said "If border effect is found to be important and if the inner three rows of five-row rod-row plots are utilised for determining the yields it will be necessary to re-examine the legitimacy of using yields per 100 plants under such conditions." The inclusion of the border rows of plots may quite easily give incorrect results. It is, therefore, necessary to discard such rows. The relative accuracy of using yields per 100 plants with the inner rows of plots

1. Standard errors of differences calculated directly from differences of adjacent pairs of plots and expressed as percentages of the mean yields of Mb. 14.

compared with using total yields is difficult to determine. The method of correlating yield of grain and number of plants per plot used previously seems to fail when any selection contains an average number of plants per plot well below the mean of the whole series. Basing results on yields per 100 plants under such circumstances was proved to be inaccurate in the experiment described in the preceding section. The mean yield per plot of the inner three rows of the 20 replications of Mb-14 grown in 6" rod-row plots where the maximum number of plants was maintained, in terms of yield per 100 plants was 1.35 lbs. The mean yield per plot of Mb-14 in similar plots where a large number of plants was removed about one month after transplanting, was 2.10 lbs. The average number of plants in the inner three rows in the first case was 81, and in the second 50. (The yields of the corresponding 12" plots are not included as this type of rod-row plot has been shown to be unsuitable). The difference between the mean number of plants in the inner three rows is large. With such a large difference the use of yields per 100 plants is definitely incorrect. Further verification of this has been obtained from the 1926 and 1927 yields of the selection 1 CPY 19 mentioned in the first section of this paper. The 1926 yields of this selection were based on an average of 55 plants per plot when the mean of all the other plots in the test was 78. In both examples where the inaccuracy of using yields per 100 plants has so far been proved the mean number of plants per plot was materially below the mean of the whole series. The use of total yields saves a certain amount of time and it is interesting to compare results worked out by both methods.

(a) Test with Mb-14 and De-18.

<i>Type of Plot</i>	<i>Method</i>	<i>Selection</i>		<i>S.E. d</i>	<i>n =</i>
		<i>Mb-14</i>	<i>De-18</i>		
6" Rod-row plot	Total				
Inner 3 rows	Yields	100	108.4	6.7%	19
Do	Yields per 100 plants	100	100.7	7.26%	19
1/117 ac.	Total				
	Yields	100	107.8	6.0%	7

None of the differences is significant, but it is interesting to notice the similarity of the results of examples (1) and (3). The average number of plants per plot of Mb-14 was 81, and for De-18, 87. (The maximum number of plants in the inner three rows of the type of plot used is 90).

(b) Tests of 1 and 2 CPY Selections, 1927

<i>Selection</i>	<i>Yield per 100 plants. Hinati =100</i>	<i>Total Yields Hinati =100</i>	<i>Average number of plants per plot</i>
1 CPY 5	122	133	85
1 CPY 15	120	126	83
1 CPY 16	117	125	83
1 CPY 3	114	121	84
1 CPY 19	112	113	79
1 CPY 17	103	113	86
Hinati	100	100	78
1 CPY 6	99	98	79
1 CPY 18	93	102	86
2 CPY 16	83	86	81
S.E.d	6.93%	6.58%	

In view of the possibility of using the total yields of the inner three rows of rod-row plots when the mean number of plants per plot is little below the maximum number and in view, also, of the fact that the use of yields per 100 plants is inaccurate when the mean number of plants per plot is much below the maximum a further experiment was laid down at Peradeniya during the *Maha* season of 1927-28 to attempt to determine (i) The relative accuracy of yields per 100 plants and total yields, and

(ii) The mean number of plants per plot below which both yields give a false estimate of the true yields.

Two pure-line long-aged paddies I-17 and P-9 were used in the experiment and were grown in ordinary 5-row rod-row plots with 6" space between plants. I-17 and P-9 plots were laid down in pairs, the position of the two selections in each pair being at random. Two pairs constituted a block. In one pair (*a*) of each block, again chosen at random, the full number of plants was left unaltered, but in the other pair (*b*) a number of plants was removed. In block I, 10 plants; in block II, 20 plants and in block III, 40 plants were uprooted respectively from the pairs labelled (*b*). The three blocks made up a replication and, in all, eight replications were laid down, making a total of 96 rod-row plots. The plants were uprooted about 3 weeks after transplanting and were taken indiscriminately from both inner and outer rows. The inner three rows were harvested separately. The total yields of grain in lbs. per plot (after sun-drying) will be found in Tables V and VI and the yields of grain per 100 plants in Tables VII and VIII. The tables are divided into three portions corresponding to the yields of plots in blocks I, II and III. The first column in each portion shows the number of plants harvested from the (*b*) plots, *i.e.*,

TABLE V
Effect of Number of Plants per Inner 3 rows of Rod-row plots on total yield per plot

Yields of grain in lbs, per plot when the average number of plants per plot is respectively 80, 74 and 61.
Pure-line paddy I-17.

Replications	80 Plants per Plot				74 Plants per Plot				61 Plants per Plot			
	Plants per plot	Yield	Adjacent plot with no plants up-rooted		Plants per plot	Yield	Adjacent plot with no plants up-rooted		Plants per plot	Yield	Adjacent plot with no plants up-rooted	
			No. of plants	Yield			No. of plants	Yield			No. of plants	Yield
a	81	1.11	88	.76	79	1.69	86	1.31	57	1.45	89	1.78
b	78	1.48	86	1.50	76	1.57	86	1.42	65	1.66	87	1.20
c	81	1.76	89	1.89	71	1.79	86	1.91	63	0.81	88	1.01
d	82	0.92	87	0.84	78	0.98	85	0.89	61	1.28	89	1.45
e	81	1.26	89	1.60	68	1.42	87	1.50	61	1.81	88	1.62
f	80	1.56	86	1.41	75	1.50	89	1.23	67	1.01	87	0.66
g	81	1.50	90	1.69	70	0.87	85	1.23	63	1.50	89	1.39
h	82	1.26	88	1.42	75	1.64	86	1.75	55	1.30	86	1.47
Total	646	10.85	703	11.11	592	11.46	690	11.24	492	10.82	703	10.58
Mean	80.75	1.356	87.875	1.388	74	1.4325	86.25	1.405	61.5	1.3525	87.875	1.3225

TABLE VI
Effect of Number of Plants per Inner 3 rows of Rod-row plots on total yield per plot

Yields of grain in lbs. per plot when the average number of plants per plot is respectively 81, 75 and 60
Pure-line paddy P-9

Replica- tions	81 Plants per Plot				75 Plants per Plot				60 Plants per Plot			
	Plants per Plot	Yield	Adjacent plot with no plants uprooted		Plants per Plot	Yield	Adjacent plot with no plants uprooted		Plants per Plot	Yield	Adjacent plot with no plants uprooted	
			No. of Plants	Yield			No. of Plants	Yield			No. of Plants	Yield
a	80	1.25	84	0.67	78	1.30	90	0.85	63	1.26	83	1.26
b	82	0.98	88	1.17	75	1.00	87	1.23	64	1.28	87	1.34
c	78	0.95	88	1.34	73	1.47	88	1.73	53	1.03	80	0.79
d	79	0.70	89	0.84	75	0.84	89	0.60	56	0.92	83	1.23
e	81	1.11	87	1.08	75	1.35	88	1.31	54	1.11	87	1.08
f	82	1.26	86	0.76	77	1.06	86	0.91	62	0.81	86	0.91
g	81	1.48	90	1.12	72	0.73	89	0.73	62	1.17	89	1.34
h	88	1.26	86	0.95	77	1.25	88	0.82	65	1.03	82	1.24
Total	651	8.99	698	7.93	602	9.00	705	8.18	479	8.61	677	9.19
Mean	81.375	1.12375	87.25	0.99125	75.25	1.125	88.125	1.0225	59.875	1.07625	84.625	1.14875

TABLE VII
Effect of Number of Plants per Inner 3 rows of Rod-row plots on yield per 100 plants

Yields of grain in lbs. per 100 plants when the average number of plants per plot is respectively 80, 74 and 61
Pure-line paddy I-17

Replica- tions	80 Plants per Plot				74 Plants per Plot				61 Plants per Plot			
	Plants per Plot	Yield	Adjacent plot with no plants uprooted		Plants per Plot	Yield	Adjacent plot with no plants uprooted		Plants per Plot	Yield	Adjacent plot with no plants uprooted	
			No. of Plants	Yield			No. of Plants	Yield			No. of Plants	Yield
a	81	1.37	88	0.86	79	2.13	86	1.52	57	2.54	89	2.00
b	78	1.90	86	1.74	76	2.06	86	1.65	65	2.55	87	1.37
c	81	2.12	89	2.12	71	2.52	86	2.22	63	1.28	88	1.14
d	82	1.12	87	0.96	78	1.25	85	1.04	61	2.09	89	1.62
e	81	1.55	89	1.80	68	2.08	87	1.72	61	2.96	88	1.84
f	80	1.95	86	1.63	75	2.00	89	1.38	67	1.50	87	0.75
g	81	1.85	90	1.87	70	1.24	85	1.44	63	2.38	89	1.56
h	82	1.53	88	1.61	75	2.18	86	2.03	55	2.36	86	1.70
Total	646	13.44	703	12.59	592	15.46	690	13.00	492	17.66	703	11.98
Mean	80.75	1.68	87.875	1.57	74	1.9325	86.25	1.625	61.5	2.2075	87.875	1.4975

TABLE VIII
Effect of Number of Plants per Inner 3 rows of Rod-row plots on yield per 100 Plants

Yields of grain in lbs. per 100 plants when the average number of plants per plot is respectively 81, 75 and 60
Pure-line paddy P-9

Replica- tions	81 Plants per Plot				75 Plants per Plot				60 Plants per Plot			
	Plants per Plot		Adjacent plot with no plants uprooted		Plants per Plot		Adjacent plot with no plants uprooted		Plants per Plot		Adjacent plot with no plants uprooted	
	Yield	No. of Plants	Yield	No. of Plants	Yield	No. of Plants	Yield	No. of Plants	Yield	No. of Plants	Yield	No. of Plants
a	80	1.56	84	0.79	78	1.66	90	0.94	63	2.00	83	1.51
b	82	1.19	88	1.32	75	1.33	87	1.41	64	2.00	87	1.54
c	78	1.21	88	1.52	73	2.00	88	1.96	53	1.94	80	0.98
d	79	0.88	89	0.94	75	1.12	89	0.67	56	1.64	83	1.48
e	81	1.37	87	1.24	75	1.80	88	1.48	54	2.05	87	1.24
f	82	1.53	86	0.88	77	1.37	86	1.05	62	1.30	86	1.05
g	81	1.82	90	1.24	72	1.01	89	0.82	62	1.88	89	1.50
h	88	1.43	86	1.10	77	1.62	88	1.10	65	1.58	82	1.56
Total	651	10.99	698	9.03	602	11.91	705	9.43	479	14.39	677	10.86
Mean	81.375	1.373	87.25	1.128	75.25	1.488	88.125	1.178	59.875	1.80	84.625	1.357

those plots from which plants had been removed, and the second column the yield of grain. The third and fourth columns refer to the (a) plots from which no plants had been removed and which were adjacent to the (b) plots.

The results may be summarised in the following form :—

<i>Yields per hundred plants</i>			<i>Total Yields</i>	
<i>Mean No. of plants per plot</i>	<i>Mean Yield</i>	<i>Mean Yield of adjacent plots with no plants uprooted</i>	<i>Mean Yield</i>	<i>Mean Yield of adjacent plots with no plants uprooted</i>
<i>Selection I-17.</i>				
80	1.68	1.574	1.356	1.388
74	1.932	1.625	1.4325	1.405
61	2.2075	1.4975	1.3525	1.3225
<i>Selection P-9.</i>				
81	1.373	1.128	1.124	0.991
75	1.488	1.178	1.125	1.0225
60	1.798	1.357	1.076	1.149

Before discussing these results attention should be drawn to the fact that total yields are not comparable, for obvious reasons, to yields per 100 plants. The comparable figures are the two sets under "yields per 100 plants," and the two sets under "total yields." It is assumed that the true yield under both methods is that of the respective adjacent plots where almost the full number of plants reached maturity. The results are striking and show that—

- (1) Even with as many as 80 or 81 plants per plot the yield per 100 plants may not be very close to the true yield, e.g., with P-9 a yield of 1.373 lbs. compares with the true yield of 1.128 lbs., an increase of 21% ; with I-17, however, 1.68 lbs. compares with 1.574 lbs., a difference of only 7%.
- (2) With 75 and 60 plants per plot the calculated yields per 100 plants vary very largely from the true yields, so largely as to render their use hopelessly misleading.
- (3) The use of total yields is preferable to that of yields per 100 plants not only when the number of plants per plot is high but even when the number is as low as 60. In all comparisons the differences under total yields are less than those under calculated yields. It would appear that with the inner rows of five-row plots the loss of plants is compensated for by an increased yield of the adjacent plants, at any rate

up to a loss of 30 plants per plot. Owing to the danger of losing grains through too much handling the number of fruiting culms per plot was not counted, so it is not possible to say whether the increased yield in plots with a small number of plants is due to increased tillering of the remaining plants or to an increased size of ear-head. It is probably due to both these causes, and it is possible that with those varieties which do not tiller freely a loss of even 15 plants would not be fully made up by the increased yield of the remaining ones.

It is obvious, however, that the use of total yields is to be preferred to calculated yields, but it is an additional safeguard against error to ensure that as many plants per plot as possible reach maturity. The methods of doing this are as follows :—

- (1) Renewing in the early weeks of the life of the plot vacancies caused by disease, land crabs or other causes.
- (2) Thoroughly draining the fields immediately after transplanting to lessen attack by crabs.
- (3) Planting a 2'–3' border of plants of any variety round the field, close to the bunds, to attract crabs and so keep them away from the plots.
- (4) Trapping crabs in pots. A method of doing this has been described by the writer (7).
- (5) Collecting crabs in the day time by means of boys.

THE USE OF LARGER-SIZED PLOTS FOR PRELIMINARY TESTING OF RICE SELECTIONS

After choosing a number of ear-heads (from 20 to 100) of the variety to be worked on the next step in the pure-line selection of rice is to multiply separately the seeds of each ear-head (or selection).

The method¹ of multiplication employed by the writer is to grow the seeds of each selection in small nurseries and from there to transplant into small plots of 5 lines of plants 6" apart with plants 6" apart in the rows. The number of plants per plot will vary with the number of seeds per ear-head, but invariably the seed obtained from each selection is sufficient for from 6 to 10 or more rod-row plots the following year. The employment of careful cultural methods in the first year's multiplication of seed and the use of a larger number of initial selections (50–100 per variety) has resulted in yields of seed from many plots

¹ The methods employed for the prevention of cross pollination and for botanical examinations of selections to detect segregation are not concerned with this paper.

of over 2 lbs. The following statement shows the yields of initial multiplication plots obtained during the last year :—

<i>Variety of rice</i>	<i>No. of selections made</i>	<i>No. of selections which yielded over 2 lbs. of seed</i>
<i>Kandimurungan</i>	70	20
<i>Hetadawi</i>	20	10
<i>Dewaredderi</i>	50	12
<i>Ratawi</i>	48	3
<i>Sulai</i>	50	23
<i>Madael</i>	50	23

Two pounds of seed are sufficient for from six to eight replications of 1/200 acre plots transplanted according to village methods and allowing for a 12" border of plants to be discarded prior to harvest. It is possible, therefore, under favourable conditions to have the preliminary testing of rice selections carried out in plots considerably larger than rod-row plots. In the early stages of pure-line selection of rice in Ceylon, where numerous varieties are necessary to supply varying local needs, principles must be interpreted in the light of expediency. The initial yields of unreplicated, unequal-sized, multiplication plots is no guide to comparative yields and the correct procedure would be to test for yield all selections which are morphologically and physiologically satisfactory. To do so would frequently, if not invariably, entail an extra year for multiplying again the small amounts of seed yielded by some selections. It would entail also the use of more experimental fields than are available. Expediency suggests, therefore, that so far as possible only those selections which yield about 2 lbs. of seed from their initial multiplication plots should be tested, and then by the use of 1/200 acre plots. When, due to less favourable conditions, most of the selections of a variety yield below 2 lbs. of seed, the use of rod-row plots will still be necessary. Larger-sized test plots transplanted according to local methods have advantages and disadvantages. The advantages are the saving of time, and the probable reduction of experimental errors. On the other hand, the seed available for six replications of 1/200 acre plots would be sufficient for thirty replications of 5-row rod-row plots, whose standard errors would be much smaller than those of six replicated 1/200 acre plots. Another disadvantage is that larger-sized plots require larger-sized fields. One replication of 20 selections in 1/200 acre plots allowing for border rows and for a space of four feet between plots to reduce the danger of cross-pollination would require about 1/5 acre. One means of circumventing this disadvantage would be to

divide the selections into two groups and test each group against the same control variety.

The experimental errors from larger-sized plots are smaller than those from rod-row plots. The following table shows the standard deviations obtained lately from different types of plots in different trials :—

<i>Type of plot</i>		<i>S.D. % of mean</i>
Rod-row	3 rows	19.6
Do	do	20.2
Do	do	15.5
Do	do	14.7
1/200 acre		15.3
Do		11.0
Do		14.4
Do		8.5
Do		14.2
1/117 acre		12.0

Direct comparisons are not possible, but there is clear indication that errors from 1/200 acre plots are smaller than those from rod-row plots. It has been said that the seed sufficient for six 1/200 acre plots is sufficient for thirty rod-row plots, but it would not be practicable to lay down thirty replications of rod-row plots except for special purposes. Considering the time necessary to lay down separately and harvest and thresh separately large numbers of replications the writer recommends the use of 1/200 acre plots whenever from 15 to 20 selections of any variety have yielded 2 lbs. or more of seed. Such tests replicated six to ten times will pick out the best and the worst yielders. Further discarding can be made on the results of the following year's test when ample seed will be available. Five ozs. of seed will supply sufficient plants for transplanting about 1/145 acre, *i.e.* for the 1/200 acre plot proper and for a 12" border of plants to be discarded just prior to harvesting. Conditions in certain parts of Ceylon render it difficult to transplant test plots. If care is taken plots may be broadcasted successfully, but frequently the stand of plants in such plots is so uneven that thinning and filling up gaps is essential. Apart from this disadvantage, broadcasted plots require more seed (about 8 ozs.) so, whenever possible, plots should be transplanted. It may be pointed out that the use of 1/200 acre plots so early in the history of a pure-line selection may render it more difficult to detect segregating lines. If proper care is taken it is not thought that this is a serious objection. It will be noticed that the experimental errors hitherto obtained with both types of plots

are large. Unless more careful cultural methods result in a reduction of these errors it will be necessary to have about 16 and 10 replications respectively of rod-row and 1/200 acre plots to be able to state if a 10% difference is significant or not. This amount of accuracy at least will be necessary for second tests.

SUMMARY

1. This paper gives an account of the further investigations of the technique to be employed in the preliminary testing of rice selections.
2. The methods of plot arrangement and of the statistical examination of results are described.
3. It is shown that border effect may be appreciable and that discarding the outer rows of 5-row rod-row plots is necessary. The discarding of border rows in all plots is advocated.
4. The use of total yields per inner three rows of rod-row plots is shown to be more accurate than the use of yields per 100 plants. As an additional safeguard it is recommended that careful cultural methods should be employed to ensure that each plot matures a high percentage of plants.
5. Attention is drawn to the possibility of using 1/200 acre plots in preliminary testing of selections. Whenever seed is sufficient for such plots their use is recommended. One or two extra border rows should be planted and discarded before harvest.
6. Transplanting instead of broadcasting the larger test plots is advocated.
7. Experimental errors of varietal tests with rice in small plots are shown to be high and selections should be replicated as many ~~times~~ as possible. Sixteen replications of rod-row plots and ten replications of 1/200 acre plots with careful cultural methods should detect 10% differences of yield.

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Belunnahara Paddy Seed Station showing Rod-Row Plots.

Measurements of the Grains of Ceylon Rices

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WITH FOUR PLATES

A knowledge of the dimensions of rice grains of different varieties is useful both for purposes of classification and for comparison with dimensions of rices in other countries. The number of villagers' varieties in Ceylon is so large that no attempt has yet been made to classify them and little interest has hitherto been taken in the exact dimensions of their grains. As the result of the work of the Department of Agriculture on the isolation, testing and distribution to cultivators of pure-line selections of indigenous rices certain of these selections have now proved their superiority over local varieties and have become of sufficient importance to warrant a more careful study of their characters. This paper gives the lengths and breadths of some of the more successful pure-line selections together with those of a few village varieties. (Plate XVII). The method of making the measurements is described and in determining the minimum number of grains which should be measured in order to arrive at a sufficiently accurate mean the opportunity was taken of comparing the variations in a pure-line selection and a village variety.

THE METHOD EMPLOYED

The lengths and breadths of grains both husked and unhusked were determined by placing the grain on a glass scale marked in millimetres and half millimetres. The glass scale was placed under a dissecting

lens. Measurements lying between 0.5 and 1.0 mm. had therefore to be judged by eye and estimates were made to the nearest 0.1 mm. It is not claimed that this method is very accurate, but the results as shown in the frequency polygons (Plates XVIII-XX) of the two pure-line selections indicate a very fair degree of accuracy for the method. The frequency polygons for a-8 (Plate XX) are not so regular as those for I-17 partly because only one hundred measurements were taken and partly because the effect of any error in judging intermediate readings will be greater in small grains than in large. The method has the great advantage, when a large number of measurements has to be made, of being rapid. After all, it is not thought that in the classification of rices by length and breadth of grains it will be possible to work to length classes of less than 0.5 mm. and breadth classes of less than 0.25 mm. The length and breadth classes used by Kikkawa¹ in the classification of Burma rice were larger than these. Thickness of rice grains is a much less useful character than length or breadth, as it varies very little in the different varieties. Precise measurements have not yet been made as the use of the glass scale is not so satisfactory for small measurements, particularly when the grain has to be held in position by hand. Rough measurements on the glass scale showed the different varieties to vary in thickness as follows: unhusked grains 2.0 mm. to 2.2 mm.; husked grains 1.8 mm. to 2.0 mm. Unless a study of other varieties brings to light greater variation, classification by thickness will mean measuring thicknesses differing by as little as 0.1 mm. A gauge with a vernier scale can be successfully used for this purpose and will be used prior to any attempt at classification according to thickness.

In order to determine the normal variation in length and breadth of both husked and unhusked grains of a pure-line selection two pure-line selections of two distinct types I-17, and a-8, were taken and 200 husked and unhusked grains of the former and 100 husked and unhusked grains of the latter were measured. At the same time similar measurements of 200 grains of the village variety *Hatiel* were made in order to compare the variation of such a rice with that of pure-line selections. The results of these measurements will be found in Tables I and II. Frequency polygons will be found in Plates XVIII-XIX.

It was then necessary to decide on the minimum number of measurements of any variety of rice grains which could be relied on to give an accurate enough measure of their length and breadth. Two hundred or even one hundred measurements take up far too much time. The standard deviations of I-17 and a-8 will be seen in Tables I and II.

1. Kikkawa, S. On the classification of cultivated rice, in Journ. Coll. Agric., Tokyo, (1912).

TABLE I
Measurements of Unhusked Grain

Name	Variety	Mean length in mm.	S.D.	C.	S.E. m	Mean breadth in mm.	S.D.	C.	S.E. m
a-8	Podiwi	6.022	0.09	1.49	0.009	3.01	0.073	2.425	0.007
I-17	Sudumawi	8.284	0.221	2.668	0.016	3.447	0.157	4.555	0.011
Hatiel	—	7.955	0.595	7.479	0.042	3.272	0.283	8.649	0.02

TABLE II
Measurements of Husked Grain

Name	Variety	Mean length in mm.	S.D.	C.	S.E. m	Mean breadth in mm.	S.D.	C.	S.E. m
a-8	Podiwi	4.337	0.188	4.335	0.019	2.652	0.137	5.16	0.014
I-17	Sudumawi	6.195	0.186	3.002	0.013	3.068	0.115	3.748	0.008
Hatiel		5.709	0.339	5.938	0.024	2.775	0.222	8.000	0.016

Theoretically, therefore, the standard error will be $\frac{\sigma}{\sqrt{n}}$ where σ = standard deviation and n = the number of measurements. The standard errors of means of twenty measurements were next worked out. These are as follows :—

TABLE III
Standard Errors of means of 20 measurements

Variety	Unhusked Grain Length mm.	Breadth mm.	Husked Length mm.	Grain Breadth mm.
a-8	0.02	0.016	0.04	0.03
I-17	0.05	0.035	0.04	0.03
Hatiel	0.13	0.06	0.07	0.05

It seems hardly necessary to insist on very high statistical accuracy for measurements which are partly based on human judgment; odds of 50 to 1 that the means are accurate between certain limits would

appear ample. If we accept these odds then for means of twenty measurements we can be certain that only once in fifty times will the measured mean differ from the true mean by more than 2.528^1 times the standard error. The largest standard error for length in the pure-line selections mentioned above is that for I-17, which is 0.05 mm. Multiplied by 2.528 this becomes 0.1264 mm., a comparatively low figure when 0.5 mm. is the least length class division feasible in any classification. The largest standard error for length in *Hatiel* is 0.13 mm. which multiplied by 2.528 becomes 0.3286 mm., a somewhat higher figure than for I-17, but still within the limits of a class division. For breadth the largest standard error for the pure-line selections is 0.04 mm. Multiplied by 2.528 this becomes 0.101 mm., a figure well within the low breadth class interval of 0.25 mm. The highest standard error for breadth in *Hatiel* is 0.07 which similarly becomes 0.177 mm. It was decided, therefore, that the mean of twenty measurements was sufficiently accurate and this number was taken in the succeeding measurements, particularly as the varieties to be measured were mainly pure-lines. Village varieties of paddies in Ceylon are very often mixtures of two or more varieties which the cultivator himself can distinguish. In any measurements of village paddy it would be more accurate to use grains of the correct type only. If this were done the standard errors would almost certainly be less than those found for the village varieties listed in Tables IV and V.

It will be noticed that the standard errors in Tables IV and V obtained from twenty measurements are either similar to, or smaller than, the theoretical errors given in Table III.

THE DIMENSIONS OF THE RICES

These will be found in Tables IV and V. Except for I-17 and *Hatiel* (means of 200 measurements) and a-8 (means of 100 measurements), the means given are from twenty measurements. From the dimensions of so small a number of varieties no attempt is being made to form arbitrary classes based on length, breadth or the $\frac{\text{length}}{\text{breadth}}$ ratio. This work will be attempted after many more varieties have been measured. It is obvious, however, that these Ceylon rices fall into two categories, those with long or medium length and fairly bold grains (*e.g.* B-11, I-17, W-15, 2415/20, etc.) and those with short and very definitely bold grains (*e.g.* a-8, k-7, E-24). The short bold-grained rices like a-8 and k-7 are closely similar to the South India *Muthusamba*.

¹ This factor has been taken from the Table of T "Statistical Methods for Research Workers" R. A. Fisher.

TABLE IV
Measurements of Unhusked Grain

Name	Variety	Mean length in mm.	S.D.	S.E. m	Mean breadth in mm.	S.D.	S.E. m	Length Breadth	Ratio
<i>Age 6 months.</i>									
R-11	Ratkunda Mawi	8.465	0.1356	0.0303	3.51	0.0725	0.0162	2.41	
B-11	Kohumawi	8.34	0.176	0.0393	3.485	0.0607	0.0135	2.39	
I-17	Sudumawi	8.284	0.221	0.016	3.447	0.157	0.011	2.40	
Hatiel	—	7.955	0.595	0.042	3.272	0.283	0.02	2.43	
P-9	Sudumawi	7.57	0.0923	0.0206	3.11	0.0917	0.0205	2.43	
W-15	Mawi	7.56	0.1237	0.0276	3.08	0.1025	0.0229	2.45	
i-10	Pulksamba	7.545	0.0888	0.0198	3.13	0.0973	0.0217	2.41	
b-13	Kurulutuduwi	7.34	0.1987	0.0444	3.225	0.1622	0.0363	2.27	
G-3	Mahamawi	7.015	0.1396	0.0312	3.08	0.1049	0.0234	2.28	
E-24	Kalukanmawi	6.51	0.1414	0.0316	3.115	0.1049	0.0234	2.09	
k-7	Surasamba	6.485	0.1432	0.032	3.43	0.0801	0.0179	1.89	
a-8	Podiwi	6.022	0.09	0.009	3.01	0.073	0.0073	2.00	
<i>Age 4½ to 5 months.</i>									
I-CP-16	Suduhonderawala	8.865	0.2282	0.051	3.46	0.0888	0.0198	2.56	
Madatawalu		8.14	0.7141	0.1597	3.145	0.2328	0.052	2.59	
Suduhonderawala		8.06	0.4894	0.1094	3.145	0.2114	0.0472	2.56	
<i>Age 4 months.</i>									
Hf-9	Sudubinati	8.115	0.214	0.0478	3.47	0.0648	0.0145	2.34	
Ib-16	Illankalayan	8.05	0.1192	0.0266	3.47	0.0725	0.0162	2.32	
HK-13	Kalubinati	7.87	0.2102	0.047	3.035	0.0945	0.0211	2.59	
<i>Age 3½ months.</i>									
2415.20	Hinkarayel	9.16	0.1539	0.0344	3.215	0.1792	0.04	2.85	
Hinkarayel		8.00	0.9067	0.2027	2.935	0.2874	0.0643	2.73	
<i>Age 3 months.</i>									
Mb-14	Morungan	8.06	0.1146	0.0256	3.505	0.076	0.0169	2.30	
Sulai		8.085	0.5256	0.1175	2.995	0.2502	0.0559	2.70	

TABLE V
Measurements of Husked Grain

Name	Variety	Mean length in mm.	S.D.	S.E. m	Mean breadth in mm.	S.D.	S.E. m	Length Breadth	Ratio
<i>Age 6 months</i>									
B-11	Kohumawi	6.29	0.1918	0.0428	2.99	0.0562	0.0126		2.10
I-17	Sudumawi	6.195	0.186	0.013	3.068	0.115	0.008		2.01
R-11	Ratkunda Mawi	6.09	0.1918	0.0428	3.025	0.0566	0.0126		2.01
Hatiel	—	5.709	0.339	0.024	2.775	0.222	0.016		2.06
P-9	Sudumawi	5.57	0.1077	0.0241	2.73	0.1025	0.0229		2.04
W-15	Mawi	5.57	0.0648	0.0144	2.75	0.1192	0.0266		2.03
i-10	Pulaksamba	5.545	0.1192	0.0266	2.675	0.0975	0.0218		2.07
b-13	Kurulutuduwi	5.53	0.0725	0.0162	2.785	0.1000	0.0224		1.98
G-3	Mahamawi	4.985	0.1000	0.0224	2.60	0.1000	0.0224		1.92
E-24	Kalukanmawi	4.67	0.1320	0.0339	2.84	0.1049	0.0234		1.64
k-7	Surasamba	4.515	0.0889	0.0199	2.97	0.0794	0.01104		1.52
a-8	Podiwi	4.337	0.0188	0.0370	2.652	0.137	0.014		1.63
<i>Age 4½ to 5 months.</i>									
1-CP-16	Suduhonderawala	6.67	0.1655	0.0370	2.955	0.0509	0.0114		2.26
Suduhonderawala		6.315	0.386	0.0869	2.895	0.5078	0.1135		2.18
Madatawalu		5.775	0.5221	0.1167	2.76	0.2398	0.0536		2.09
<i>Age 4 months.</i>									
Ib-16	Ilankalayan	5.855	0.1606	0.0359	2.965	0.0608	0.0136		1.97
Hk-13	Kaluhinati	5.855	0.1539	0.0344	2.79	0.1077	0.0241		2.10
Hf-9	Suduhinati	5.785	0.1761	0.0393	2.97	0.0686	0.0153		1.95
<i>Age 3½ months.</i>									
2415/20	Hinkarayel	6.825	0.1712	0.0383	2.85	0.0943	0.0211		2.39
Hinkarayel		6.255	0.6117	0.1368	2.575	0.2293	0.0513		2.43
<i>Age 3 months.</i>									
Mb-14	Morungan	6.02	0.1144	0.0256	2.955	0.0608	0.0136		2.04
Sulai	—	6.015	0.2856	0.0639	2.61	0.2596	0.0581		2.39

As large quantities of Burma rice are imported into Ceylon it is interesting to compare the dimensions of such rice with the commonly grown Ceylon rices. The bulk of the rice imported from Burma is milled chiefly from the variety *Ngasein*. The dimensions of this rice are given by Hendry¹ as

husked grain length 5.60 to 6.40 mm.

$\frac{\text{length}}{\text{breadth}}$ 2.00 to 2.40 mm.

unhusked grain length 7.75 to 9.00 mm.

$\frac{\text{length}}{\text{breadth}}$ 2.40 to 2.80 mm.

It will be seen that most of the commonly grown Ceylon rices such as *Mawi*, *Honderawala*, *Hinati*, *Morungan* and *Hinkarayel* come either within or very close to the class limits given for *Ngasein*.

COMPARATIVE VARIATION IN A PURE-LINE SELECTION AND A VILLAGE VARIETY

The relative variation of pure-line rices and an unselected village rice may be judged by the coefficients of variability (C) in Tables I and II. As would be expected the coefficients of variability of the village rice are always greater, appreciably greater for length and breadth of unhusked grains and breadth of husked grains, and slightly greater for length of husked grains.

The frequency polygons Plates XVIII-XX enable an opinion to be formed on the purity of the three varieties. Village *Hatiel* is undoubtedly a mixture of two or more types having at least two distinct length and breadth measurements. Considering the method of measurement used the polygons for I-17 and a-8 are fairly normal and indicate that these selections are pure for grain size. As has been mentioned before the errors in measurement affect the small grained rice a-8 more than the larger grained rices; moreover, only one hundred measurements were taken and the resulting frequency polygons for a-8 are not so satisfactory. When comparing the polygons of I-17 and Village *Hatiel* it should be noted that the scales are dissimilar and rather disguise the wider range of variation in the village rice.

1. Hendry, D. Rice in Burma, in Tropical Agriculture V. 3. (p. 51, 1928)

EXPLANATION OF PLATES

Plate XVII

Letter	Selection	Variety or Varietal Extraction
a	B-11	Mawi
b	E-24	Kalukanmawi
c	I-17	Mawi
d	R-11	Ratkundamawi
e	W-15	Mawi
f	2415/20	Hinkarayel
g	1-CP-16	Suduhonderawala
h	Ib-16	Illankalayan
i	Hf-9	Suduhinati
j	Hk-13	Hinati
k	Mb-14	Morungan
	a-8	Podiwi
m	b-13	Kurulutuduwi
n	G-3	Mahamawi
o	i-10	Puluksamba
p	k-7	Surasamba
q	P-9	Sudumawi
r	Village paddy	Hatiel
s		Hinkarayel
t		Madatawalu
u		Suduhonderawala
v		Sulai

Plate XVIII

Frequency Polygons, unhusked grain

- Fig. 1. I-17. Length
 Fig. 2. I-17. Breadth.
 Fig. 3. Village *Hatiel*. Length.
 Fig. 4. Village *Hatiel*. Breadth.

Plate XIX

Frequency Polygons, husked grain

- Fig. 1. I-17. Length.
 Fig. 2. I-17. Breadth.
 Fig. 3. Village *Hatiel*. Length.
 Fig. 4. Village *Hatiel*. Breadth.

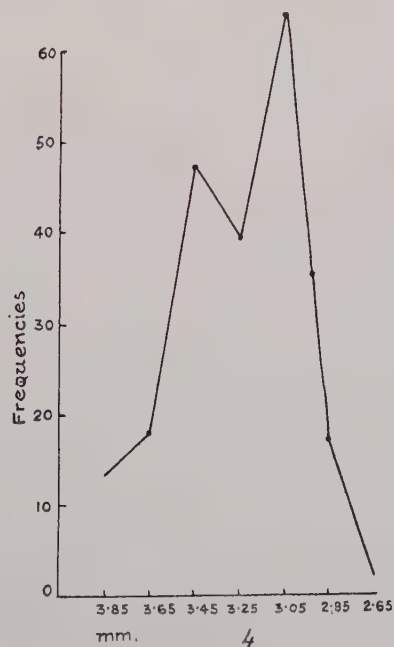
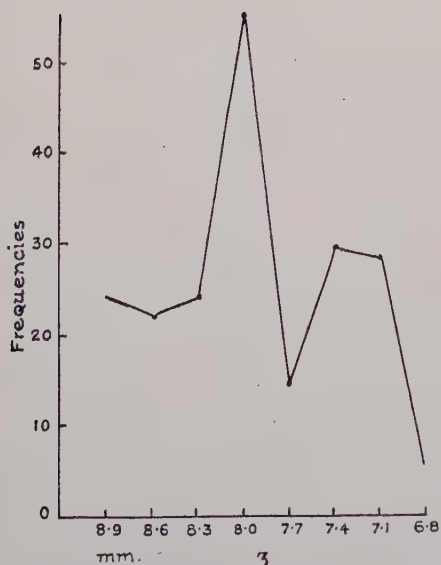
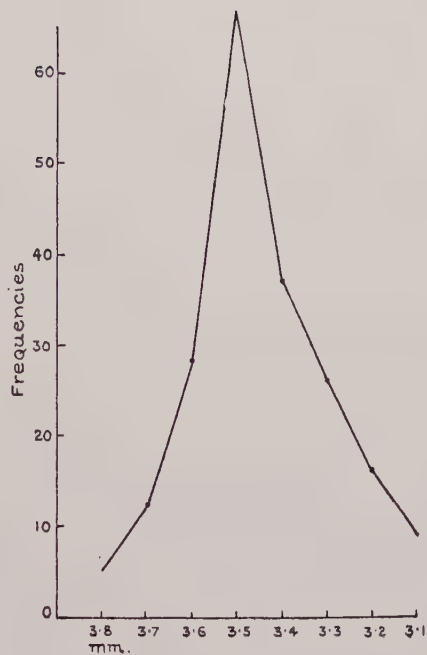
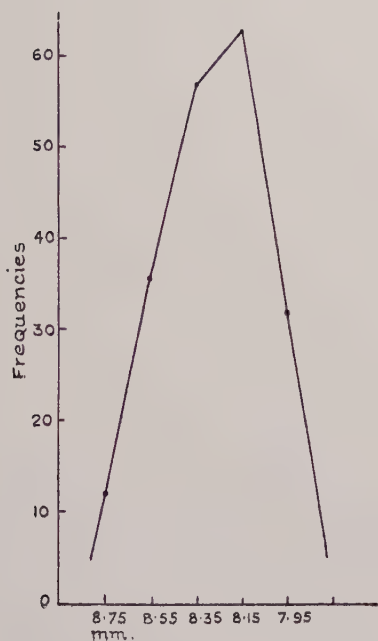
Plate XX

Frequency Polygons

- Fig. 1. a-8. Length, unhusked grain
 Fig. 2. a-8. Breadth, " "
 Fig. 3. a-8. Length, husked grain
 Fig. 4. a-8. Breadth, " "



Common Ceylon Rices.



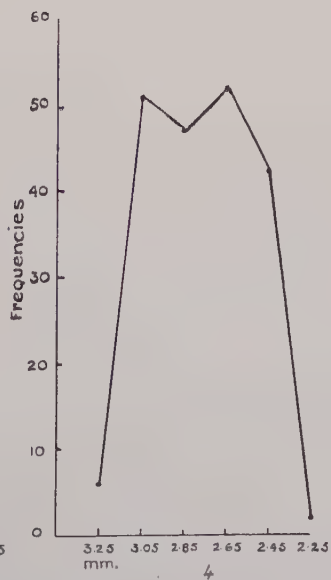
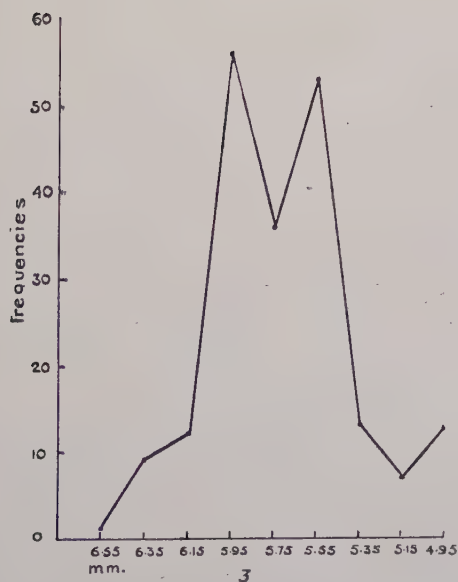
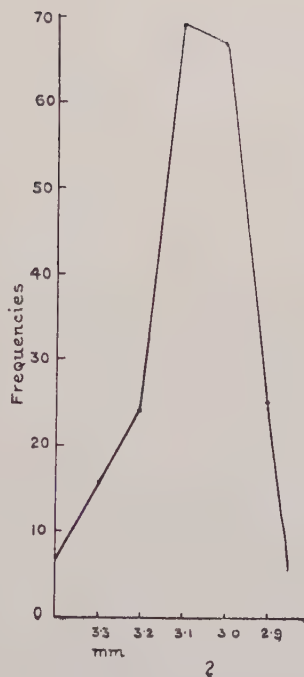
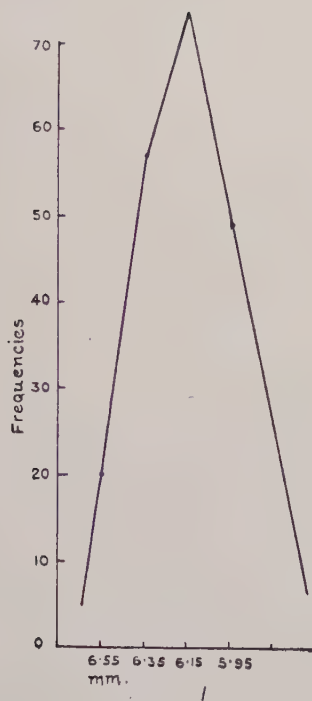
Frequency Polygons, Unhusked Grain

Fig. 1.—1-17 Length

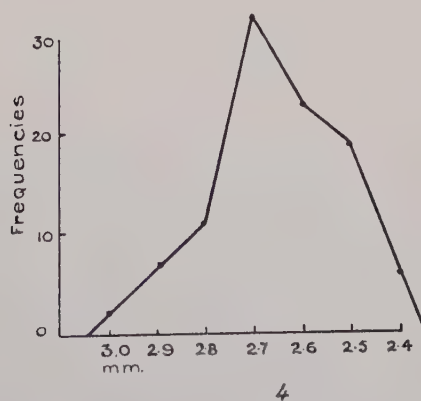
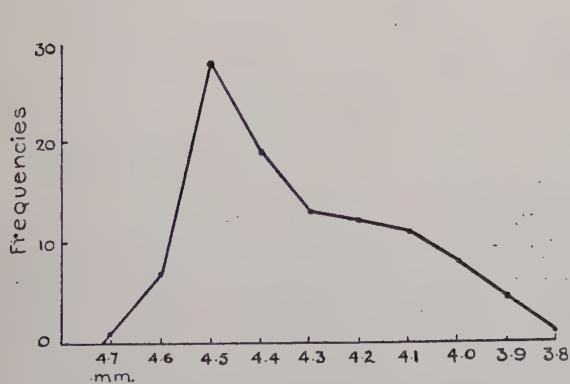
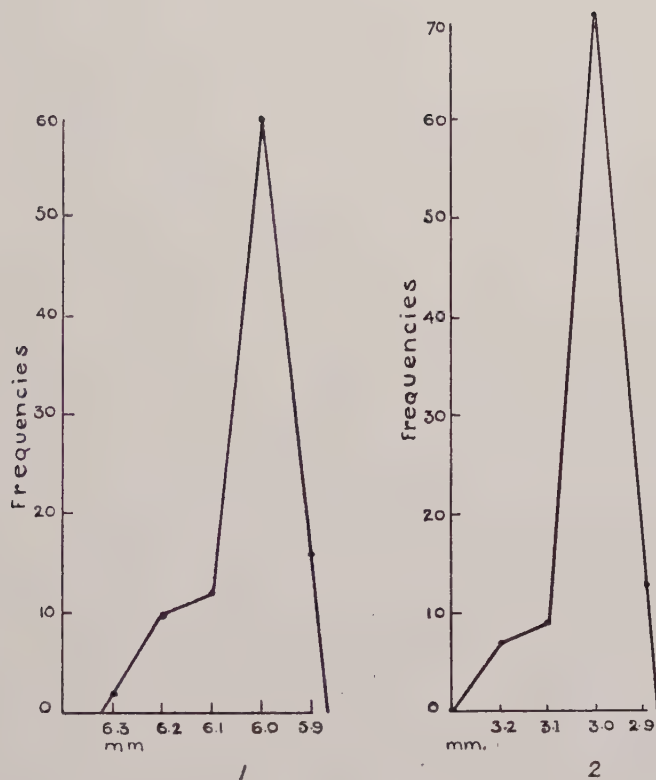
Fig. 2.—1-17 Breadth

Fig. 3.—Village Hatel. Length

Fig. 4.—Village Hatel. Breadth



Frequency Polygons, Unhusked Grain
 Fig. 1.—1-17 Length
 Fig. 2.—1-17 Breadth
 Fig. 3.—Village Hattel. Length
 Fig. 4.—Village Hattel. Breadth



Frequency Polygons.

Fig. 1.—a-8. Length, unhusked grain Fig. 2.—a-8. Breadth, unhusked grain
 Fig. 3.— „ „ husked grain Fig. 4.— „ „ husked grain

Sclerotium Rolfsii Sacc. in Ceylon

BY

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WITH TWO PLATES

INTRODUCTION

Sclerotium Rolfsii occurs in many regions, especially those of the tropics and sub-tropics, and on a large number of hosts. In a recent list of fungi occurring on economic plants in the United States of America (1), the fungus is given as the cause of stem-rots of some forty-four host plants. Briton-Jones (2) attributed to *S. Rolfsii* a root-rot of globe artichoke in Egypt, and Small recorded the fungus in Uganda in association with a *Fusarium* wilt of carnations (3) and a wilt or root disease of beans (*Phaseolus* sp.) caused by *Sclerotium* (now *Rhizoctonia*) *bataicola* (4). In the Uganda cases, *Sclerotium Rolfsii* was regarded as of secondary account. Van Hall (5) recorded the fungus on tobacco in the Dutch East Indies, and Palm (6) reported it as the cause of a root-rot of tobacco in Sumatra which was capable of doing much local damage at times. Palm and Fulmek (7) listed it also as a parasite of *Mimosa invisa* in Sumatra. In Malaya, again, Sharples (8) gave it as the cause of a disease of Jerusalem artichoke, and Rhind (9) as the cause of a disease of groundnut in Burma. It has also been recorded in St. Vincent (10) as a cause of damage to cotton seedlings in low-lying places, and Maublanc (11) recorded it in West Africa on groundnut. Tisdale (12) reported it as the cause of a disease of seedling rice in Louisiana, and Teodoro and Bogayong (13) as the cause of a similar disease in the Philippine Islands.

A study of the literature shows that *Sclerotium Rolfsii* is regarded at one time as a dangerous parasite and at another as a weak parasite or as a saprophyte or secondary fungus. Its distribution being world-wide, it is not surprising that it has been found in Ceylon. Petch (14) attributes to it (under the name *S. zeylanicum*) a disease of tea seedlings.

and it was recorded in 1924 on *Dolichos Hosei* by Gadd (15). Towards the end of 1926 it was found growing on leaves decaying on soil that had carried groundnuts and on the collars of diseased chilli plants gathered in the Galle district. It was also found in January 1927 growing over the surface of the soil of sugar-cane plots at Peradeniya and apparently causing no disease. In the case of disease which led to the investigations recorded in this paper, *Sclerotium Rolfsii* occurred on groundnut plants. It was found alone in association with *Rhizoctonia Solani* Kühn. The sclerotia of the two fungi were formed plentifully and conspicuously on the aerial parts of certain diseased groundnut plants; they differed in size, shape and colour and were therefore distinguishable with ease. Those of *Sclerotium Rolfsii* measured from 0.3 to 0.7 mm. in diameter, sclerotia of 1.0 mm. diameter being rare (Plate XXI, fig. 1). As they may fall readily from their substratum, they were found in numbers on the surface of the soil. It is worthy of note that the fruiting stage of *Rhizoctonia Solani* (*Corticium vagum* B. and C.) was found on the lower surfaces of apparently healthy groundnut leaves.

The stems of groundnut plants which were attacked only by *Sclerotium Rolfsii* were affected at ground level or at a higher point, and the leaves and petioles were dried and withered. White hyphae occurred in the form of white strands or fan-shaped masses on the stems and dead leaves of diseased plants, the majority of which were affected only in stems and leaves. In a few cases, however, the plants had been attacked at the collar. In all cases, again, the roots were healthy. The fungus appeared to have spread from plant to plant by contact between diseased stems and leaves and also by means of mycelium which developed from fallen sclerotia. The latter type of growth was that of a saprophytic fungus which could thrive on decaying matter.

Both superficial and internal hyphae of *Sclerotium Rolfsii* were hyaline. They measured up to 6 μ in diameter, and clamp-connections were found on the superficial hyphae. No fruiting stage of *Sclerotium Rolfsii* has been observed.

CULTURES OF SCLEROTIUM ROLFSII

Pure cultures of *Sclerotium Rolfsii* were obtained from single sclerotia which were taken from diseased plants, washed in water, and placed on maize-meal agar. When bacterial contamination occurred, pure growths were obtained by sub-culturing the advancing hyphae. The fungus was grown on various media, and the following notes of its characteristics on different substrata are given.

(a) *Maize-meal agar.* Hyphal growth on this medium was vigorous. It took the form of threads which united into strands on the surface of the medium and on the glass of the tube. A tough white film of mycelium was formed eventually on the medium, and in five days the beginnings of sclerotial formation could be noted. Young sclerotia were formed on the hyphal strands. They were at first small white rounded bodies and often were covered during their growth with drops of moisture. They changed colour and became buff-yellow, orange-brown and finally purple-brown. In shape they were spherical, globose or oval, and they varied in diameter from 1 to 2 mm. An average diameter of fifty sclerotia lay between 1.25 to 1.5 mm. Young sclerotia appeared to be stalked. Mature sclerotia were smooth and shining, and the point of attachment was often marked by a dimple. Continued sub-culturing of the fungus on maize-meal agar resulted in a diminution of the size of the sclerotia. After six generations, however, one of the sub-cultures yielded abnormally large sclerotia which measured as much as 3.5 mm. in diameter, but sub-culturing of these large sclerotia resulted in growths of normal sizes.

In culture the hyphae varied from 5 to 7 μ in diameter; lateral branches may be only 2 μ in width. The hyphae had a tendency to unite into strands, and a single hypha may give rise to several branch hyphae at one point. Branch hyphae may or may not be constricted at their points of origin, and the first septum may be placed near the base. Clamp-connections were found frequently. The sclerotia were brown externally and white internally. There could be distinguished in microtome sections an epidermis consisting of a layer of yellow-brown hyphae which was 1 to 2 μ in thickness and was divided into rectangular cells, a cortex which was from 15 to 20 μ in thickness and consisted of hyphae divided into hexagonal, thick-walled, pseudo-parenchymatous cells and a medulla which was made up of short stout hyphae and showed numerous intercellular spaces. Differentiation into the three layers, however, was not invariably marked and clear.

(b) *Sweet potato sterilised by boiling.* On this medium in Erlenmeyer flasks normal sclerotia were formed in six days, and five days later abnormally large sclerotia of various shapes and measuring up to 8 mm. in diameter were found (Plate XXI, fig. 3). The large sclerotia germinated by sending out hyphae from more than one point on their surfaces.

(c) *Dadap leaf sterilised by boiling.* *Sclerotium Rolfsii* grew well on chopped dadap leaves in Erlenmeyer flasks and formed abundant masses of sclerotia in four days (Plate XXI, fig. 4). In three weeks the dadap leaf medium had become a mass of mycelium and sclerotia.

On dadap leaf soaked in a strong solution of sugar and boiled, the fungus formed sclerotia in aggregations which were as much as 1 cm. in diameter (Plate XXI, fig. 2).

(d) *Filter paper*. On filter paper soaked in standard nutrient solution and sterilised few sclerotia were formed, while innumerable sclerotia were produced by growths of the fungus on filter paper moistened with distilled water.

(e) *Bacto-prune agar*. On this medium sclerotia were formed in sixteen days. They were of normal size. (Plate XXII, fig. 6).

(f) *Leaf mould*. This medium was sterilised by dry heat and was moistened with distilled water. Only very fine hyphae were formed; they died off in five weeks without forming sclerotia.

(g) *Sterilised sand*. The sand was treated in the same way as the leaf mould. Hyphal growth was poor and the fungus died.

(h) *Potato slab sterilised*. The slabs were kept in Roux tubes. Growth of the fungus was luxuriant and sclerotia were formed in three days. The shrivelled slabs subsequently became masses of sclerotia.

Maize-meal agar, sweet potato, dadap leaf, prune agar and filter paper moistened with water are media which induce a vigorous growth of *Sclerotium Rolfsii*. The sizes of the sclerotia formed by the fungus vary with the nature of the medium and also with the moisture content of the tube, flask or dish used.

VITALITY OF THE SCLEROTIA

Sclerotia were taken from a culture on May 14, 1926, and, after being dried for a week on blotting-paper, were stored in a sterile corked tube. On August 31, 1926, that is, after 109 days, samples of the sclerotia were sown on maize-meal agar and all germinated in two days' time. When similar samples of the stored sclerotia were sown on January 20, 1927, that is, after a rest of 251 days, only three out of eleven sclerotia germinated slowly in six days. A month later, after 281 days, further attempts to germinate stored sclerotia were unsuccessful. It will be noted, then, that the sclerotia of *Sclerotium Rolfsii* may lie dormant for three months and may germinate at the end of that time if conditions are favourable and also that similar sclerotia may lose the power of germination after nine months or more.

INOCULATION EXPERIMENTS

The object of the experiments was to ascertain to what extent and under what conditions *Sclerotium Rolfsii* was parasitic on the ground-nut and other host plants. The latter included various economic plants, vegetables, ornamental plants and green manures. Experiments were

conducted with seedlings and with older plants in pots and in the field. Soil inoculations were also performed in order to determine whether *Sclerotium Rolfsii* would attack the roots of plants exposed to it in the course of their growth.

(a) *Seedlings*. The plants employed in the experiments were grown from sterilised seed in pots of sterilised soil and were inoculated by placing small pieces of culture medium containing mycelium of the fungus in contact with the stems of the plants at ground level or by spreading the fungus over the soil of the pots in the form of fragments of medium. The inoculated plants were covered with bell-jars for twenty-four hours or were kept in a glass inoculation-cage and control plants were kept in the case of each host plant. No disease occurred among the control plants. The following table gives the results obtained.

Date of Sowing	Date of Inoculation	No. of Plants Inoculated	Point of Inoculation	Results		Nature of Infection and Remarks
				Positive	Negative	
<i>Crotalaria juncea</i> (sunn hemp)						
7.10.26	12.10.26	10	Stems at ground level.	10	—	Damped-off within 2 days.
7.10.26	27.10.26	10	do	10	—	Damped-off within 5 days.
14.10.26	9.12.26	6	do	8	—	Stem rot. Plants died within 17 days ; 2 non-inoculated plants were attacked and killed by spreading hyphae.
<i>Hibiscus esculentus</i> (bandakai)						
6.10.26	12.10.26	8	do	8	—	Damped-off within 2 days.
6.10.26	27.10.26	7	do	7	—	Damped-off within 3 days.
6.10.26	22.11.26	6	do	—	6	Nil.
6.10.26	13.12.26	4	do	1	3	In 13 days, a brown discoloration on the stem of one plant about 3 inches long, surrounded by white hyphae. Droplets of a yellow liquid oozing out of diseased tissue. The plant died of stem rot in 19 days.
<i>Indigofera endecaphylla</i>						
29.9.26	12.10.26	Numerous	Surface of soil	Numerous	—	Culture medium mixed with water and spread over soil. Damped-off in a few days.
<i>Phaseolus vulgaris</i> (French bean)						
20.10.25	29.10.25	10	Stems at ground level.	10	—	Damped-off within 4 days.
4.11.25	14.12.25	8	do	8	—	Damped-off within 5 days.

Date of Sowing	Date of Inoculation	No. of Plants Inoculated	Point of Inoculation	Results		Nature of Infection and Remarks
				Positive	Negative	
21.5.25	27.5.26	5	Stems at ground level.	5	—	Damped-off within 2 days.
<i>Gossypium</i> sp. (Cambodia cotton)						
8.1.26	15.1.26	9	do	6	3	Damped-off within 4 days.
8.1.26	18.5.26	7	Roots	—	7	Hyphae ascended to the collar of all the plants and produced a plentiful supply of sclerotia but were unable to effect penetration.
<i>Capsicum annum</i> (chilli)						
31.5.26	26.6.26	14	Surface of soil	14	—	Damped-off in 2 days. Pieces of culture media containing hyphae placed on soil away from plants.
<i>Beta vulgaris</i> (beet)						
22.7.26	6.8.26	Numerous	Stems at ground level	Numerous	—	Damped-off in 3 days.
<i>Raphanus</i> sp. (radish)						
30.6.26	19.8.26	5	Swollen root at ground level	5	—	Upper portion of swollen root inoculated. Plants collapsed in 5 days; roots reduced to a sodden mass.
30.6.26	9.7.26	18	do	18	—	Damped-off in 3 days.
30.6.26	6.8.26	11	Swollen root at ground level	11	—	Swollen roots of 10 plants rotted in 3 days together with a rot at the base of the leaf-stalks. The remaining plant withered off a few days later.
<i>Dolichos Hosei</i>						
10.6.26	9.7.26	6	Stems at ground level	2	4	Leaf and stem rot; 2 plants killed by leaf and stem rot. The remaining 4 survived by producing new shoots.
10.6.26	18.8.26	7	do	6	1	
<i>Vigna catieng</i> (cowpea).						
4.11.25	9.11.25	10	do	8	2	Damped-off within 4 days.
<i>Solanum lycopersicum</i> (tomato)						
13.5.26	22.5.26	14	Surface of soil	14	—	Pieces of culture medium on surface of soil. Hyphae spread from the culture medium to the plants which damped-off in 2 days.
13.5.26	29.5.26	Numerous	do	Numerous	—	Pieces of culture medium spread over soil. Plants damped-off within 3 days.

Date of Sowing	Date of Inoculation	No. of Plants Inoculated	Point of Inoculation	Results		Nature of Infection and Remarks
				Positive	Negative	
13.5.26	27.6.26	8	Stems at ground level	8	—	Damped-off within 4 days.
<i>Solanum Melongena</i> (brinjal)						
7.5.26	22.5.26	9	Surface of soil	9	—	Damped-off within 24 hours.
<i>Melon</i> (musk)						
14.9.26	23.9.26	20	Stems at ground level	20	—	Damped-off within 3 days.
14.9.26	12.10.26	5	do	5	—	Damped-off in 24 hours.
<i>Camellia theifera</i> (tea)						
10.12.25	26.1.26	4	Stems at ground level	—	4	Hyphae grew superficially over lower portion of stem and on surface of soil and produced sclerotia but failed to effect penetration.
<i>Hevea brasiliensis</i> (rubber)						
4.9.26	29.9.26	3	do	—	3	Same as tea.
<i>Arachis hypogaea</i> (groundnut)						
15.6.26	22.6.26	10	do	4	6	Infection successful in 4 plants with the formation of a discolored diseased area. With growth the plant resists the fungus.
<i>Zea Mays</i> (maize)						
19.11.26	27.11.26	7	do	20	—	Within 12 days the inoculated seedlings died together with 13 non-inoculated plants in the same pot.
19.11.26	13.12.26	5	do	5	—	Within 13 days a rot at the collar killed the seedlings. This pot was in a glass cage.
19.11.26	13.12.26	5	do	—	5	This pot was kept in a glass cage for two days and then exposed in the shade. Only the outer leaf sheaths were affected and the fungus did not proceed further.
<i>Oryza sativa</i> (paddy)						
13.1.27	25.1.27	Many	Surface of soil	—	All	Culture medium mixed with water and spread over soil surface. The outer sheaths only were affected and the plants survived infection. Pots kept in glass cage.

Of the eighteen species of plants used in the above experiments only three, namely, tea, rubber and paddy seedlings, were totally unaffected by the fungus. In the case of the *Dolichos* seedlings, the hyphae ascended

the plants and killed back leaves and stems from the tops of the plants. In groundnut seedlings, certain of the plants healed the stem scars caused by attack of the fungus at the point of inoculation and recovered. Most of the other seedlings which were affected by the fungus damped-off or toppled over owing to stem breaks at the points of inoculation. Cotton seedlings were susceptible to attack when seven days old and became resistant with age, for seedlings of four months and ten days were not attacked. In the case of bandakai seedlings, positive infections were obtained on plants of six to twenty days of age and only one successful inoculation out of ten attempts was obtained with plants of six to nine weeks of age.

Again, a warm humid atmosphere aided infection and also the progress of the fungus after infection. Five maize seedlings which were kept in a glass cage after inoculation were killed by the fungus while a similar group of maize seedlings which was inoculated in the same way and kept in the same glass cage for a limited period, during which the plants were attacked by the fungus and after which the pot was placed in the shade of the pot-culture house, survived infection and grew into healthy plants. *Sclerotium Rolfsii* could infect groundnut seedlings, but was unable to effect complete destruction and kill the plants and could not be regarded as other than a weak parasite of this host.

(b) *Older plants in pots and in the field.* Infection experiments on roots, stems and leaves of the undernoted plants were carried out in order to determine the extent to which *Sclerotium Rolfsii* was capable of attacking them.

(i) *Alocasia cucullata.* Healthy plants growing in sterilised soil were inoculated with pieces of culture medium placed in contact with the roots, the sheathing leaf bases and the stem at the collar. In the case of root inoculations, hyphae of the fungus ascended to ground level in three days and formed sclerotia on the surface of the soil. The outer leaves lost their colour and became rotten, and in the space of five weeks the rhizomes of the inoculated plants were masses of sodden tissue and the plants themselves died. In the case of those which were inoculated at the sheathing base of the leaves, a soft rot which involved only the outer leaves was caused; the rhizomes remained healthy and formed new shoots. The plants which were inoculated at collar wounds were attacked severely, rhizomes and leaf stalks being converted into a rotten mass in three weeks.

(ii) *Colocasia antiquorum.* Inoculations were made on roots, at the sheathing base of the leaves and in wounds at the collar. In every case infection occurred and produced a vigorous growth of mycelium and sclerotia on leaves and leaf-stalks which in turn caused a soft rot

of the leaves and led to their death. The rhizomes of the plants, however, were unaffected.

(iii) *Chilli*. Adult plants in the field were used in the experiments. Root inoculations were made by ensuring contact (without wounds) between roots and pieces of culture medium and also single sclerotia. In the case of three plants which were treated with pieces of medium containing only hyphae, the leaves began to droop and lose colour after three days. A growth of hyphae enveloped the stems at the collars, and a few days later the plants withered and broke off at ground level. In the case of another plant, among the roots of which sclerotia were placed singly, the leaves drooped in six days and the plant withered in a further two days. Similar root inoculations were made on plants grown from seed in sterilised soil and similar results were obtained. It was found in all cases that the roots of the plants were unaffected by the fungus and that they remained healthy. The fungus made its successful attack in each case at the collar and caused withering of the aerial parts of the plants by working upwards. Stem inoculations were made by placing fragments of culture medium containing hyphae on stems and branches, the inoculum being protected for twenty-four hours with moist cotton-wool. The fungus was found to penetrate readily the cortical tissues of stems and branches and to cause affected parts to wither in four days.

(iv) *Caladium*. Inoculations of leaf stalks were made by placing pieces of medium in contact with their lower portions. In the case of plants that were covered with bell-jars, the attack of the fungus was severe. In other uncovered cases, attack was local and did not extend. The covered plants died while the uncovered plants survived.

(v) *Betel*. A soft rot of the stems of betel plants was produced by placing pieces of culture medium in contact with stems at ground level. Strands of hyphae overran the stems of the plants and formed many sclerotia.

(vi) *Tomato*. Root inoculations of tomato similar to those of chilli had similar results. After two days white hyphae enveloped the stems at ground level and after four days sclerotia were formed and the leaves of the plants were wilting and losing colour. A brown discolouration was formed on the stems, and the plants withered and died. The roots were not attacked. Single sclerotia were inserted in stem wounds of two plants in the field. The wounds were bound with moist cotton-wool and tape which were removed after four days. In the case of one plant, no infection occurred; in the case of the other which happened to be sheltered by a tea bush infection was severe, the fungus growing over the stem and killing many branches in its progress.

(vii) *Tea*. Inoculations similar to those of chilli roots were made on seven four-and-a-half-months' old tea seedlings growing in sterilised soil in pots. The hyphae of the fungus ascended the stems, in two cases for about two inches, and sclerotia were formed at ground level, but no penetration took place and the plants remained healthy. The roots and stems of the seven plants were examined microscopically for the presence of hyphae with negative results.

(viii) *Groundnut*. The roots of seven young plants which were raised from seed in pots of sterilised soil were inoculated as above. Two plants succumbed to attack at the collar in twenty-four days; the other five plants were unaffected. Stem inoculations made without wounds at about four inches from the ground and shoot and leaf inoculations proved successful in every case. In the case of stem inoculations, the plants were killed back; in the case of the shoots and leaves, attack was local and did not extend over the plants.

(ix) *Potato*. Three potato shoots about six inches high were inoculated at ground level with the usual piece of medium containing hyphae of the *Sclerotium* and were covered with bell-jars for twenty-four hours. Two days later the plants damped-off. A soft stem-rot was also caused in plants which were more than a month old.

(x) *Sweet potato*. Stem inoculations at ground level caused the plants to damp-off.

(xi) *Delphinium*. Four plants were inoculated at ground level and were placed in a glass cage. All wilted in three days.

The above results show that *Sclerotium Rolfsii* was capable of causing rots of certain parts of certain plants, especially stem-rot of chilli, tomato, betel and groundnut, and also damping-off of shoots of potato and sweet potato and of *Delphinium*. The fungus was unable to attack a woody seedling like that of tea. It was shown again that the presence of moisture may be a factor of importance in deciding the degree of infection, and also that the fungus was only weakly parasitic on groundnut.

(c) *Infected soil*. *Sclerotium Rolfsii* was grown in quantity on dadap leaves and, after sclerotial formation had taken place freely, the leaves and fungus were buried in thick layers at depths varying from one to six inches in pots of sterilised soil. The roots of the experimental plants had every chance of coming into contact with the fungus in the soil and the fungus of attacking the plants. The plants employed were French bean, chilli, radish, maize, melon, bandakai and *Crotalaria juncea*, and all were grown from sterilised seed in sterilised soil. Control plants were grown in uninoculated soil. In the cases of radish, chilli,

maize and bandakai no infections were obtained although the experiments with those plants were repeated. Five out of twelve seventeen-day-old *Crotalaria* seedlings damped-off in a pot in which the fungus was buried one inch deep, and five out of seven melon seedlings of the same age and exposed to the fungus at the same depth behaved in a similar manner. A day later, two out of six melon seedlings damped-off in a pot in which the fungus was three inches below the surface. In the case of French beans of about two weeks of age, four out of seven seedlings damped-off in the one-inch pot, six out of eight in the two-inches pot, four out of nine in the three-inches pot and one out of five in the four-inches pot. The fungus seemed unable to come to the surface when buried deeper than four inches.

In all cases of damping-off, the roots of the plants were unaffected by the fungus. The hyphae ascended to the surface of the soil and attacked the plants at ground level. All the control plants remained healthy. The above results showed that under certain conditions it might be difficult to raise certain plants in the presence of *Sclerotium Rolfsii* in the upper four inches of the soil.

(d) *Cuttings*. Cuttings of *Indigofera endecaphylla*, *Dolichos Hosei* (*Vigna oligosperma*) and *Piper betle* (betel) were exposed to the fungus at depths of one and two inches in pots of sterilised soil. Controls were kept. The cuttings of *Indigofera* and *Dolichos* struck readily, established themselves strongly and were not affected in any way by the fungus. In the case of betel, again, three out of seven cuttings were attacked at ground level five days after planting in the one-inch pot, and one out of seven in the two-inches pot. The remaining cuttings, however, were not attacked; they established themselves with success. The results show that certain plants, for example, *Indigofera*, that are susceptible to *Sclerotium* attack in the seedling stage may be established in infected soil by means of cuttings. On the other hand, betel is usually propagated by cuttings and it might be difficult therefore to establish plants in infected soil.

The following conclusions may be drawn from the experiments:—

(i) *Sclerotium Rolfsii* can damp-off the seedlings of certain plants when it is brought into contact with the stems. Certain plants which are liable to attack in their early stages become immune with age.

(ii) The fungus is able to cause stem disease or collar-rot of a number of plants, for example, chilli, tomato, betel and groundnut, through its habit of attacking its host plants at the collar. It may also cause root disease of *Alocasia* and radish, a damping-off of young shoots of potato, sweet potato and *Delphinium* and a leaf-rot of *Colocasia antiquorum*.

(iii) With regard to conditions of infection, it may be said that *Sclerotium Rolfsii* may be detrimental to the raising of certain plants from seed, for example, French bean, *Crotalaria juncea* and melon, if the fungus is present in the upper four inches of the soil, and that warm humid conditions assist the attack of the fungus and enable it to establish itself in the tissues of its host and to cause disease.

(iv) With regard to the parasitism of *Sclerotium Rolfsii* on groundnut, the fungus may cause a stem disease under conditions favourable to itself. It is, however, only a weak parasite of groundnut stems. This conclusion is supported by field observations to the effect that *Sclerotium Rolfsii* is found frequently on groundnut plants which have been attacked by *Rhizoctonia Solani* and seldom on plants attacked by itself only.

CONTROL OF SCLEROTIUM ROLFSII

In the case, for example, of disease of groundnut caused by the fungus, the following measures may be recommended:—

(i) The burning of diseased plants *in situ* after the nuts have been harvested.

(ii) The collection and destruction by fire of dead leaves and decaying matter which may harbour the fungus.

(iii) The burying in holes or trenches to a depth of nine inches or one foot of the surface soil of affected areas.

(iv) The avoidance of conditions favourable to the fungus and unfavourable to the plants exposed to the fungus, for example, overcrowding of plants, heavy shade and lack of drainage.

IDENTITY OF THE CEYLON FUNGUS

The fungus called *Sclerotium Rolfsii* Sacc. in this paper agrees in all respects with Saccardo's description of the fungus of that name and without doubt is named correctly. Ceylon isolations have been named at the Imperial Bureau of Mycology as *Sclerotium Rolfsii* and have also been compared with an isolation of a similar fungus made from sugarcane in British Guiana and determined by the Imperial Bureau of Mycology and with a culture provided under the same name by the Centraalbureau voor Schimmelcultures in Holland. The Guiana, the Dutch and the Ceylon *Sclerotium Rolfsii* were grown from single sclerotia on potato-dextrose agar, maize-meal agar and dadap leaf, and it was noted that the mode of growth was similar in all three strains on both the solid media and the dadap leaf. After seven days, the Guiana fungus had formed an abundance of white immature sclerotia on the solid media, whereas the Dutch and Ceylon strains had produced only a few sclerotia. On dadap leaf the Guiana and Ceylon strains

had formed numbers of sclerotia in eleven days, while the Dutch strain had formed only a few. Judged at a later date by sclerotial-formation, the Guiana fungus appeared to be more active than the Dutch and Ceylon forms. It also differed from the others in the initial deeper purple-brown colouring of its sclerotia, but the sclerotia of all three strains were alike in colour and size after twenty-six days. They were commonly of 1 to 1.5 mm. in diameter with a limit of 2 mm. Clamp-connections were common in the Ceylon strain, less common in the Guiana strain and rare in the Dutch strain. There were, therefore, certain points of difference between the strains, but they were of only minor account. They did not alter the fact that the three strains could be named in the same way.

In 1921 the writer brought to Ceylon from the Pusa Herbarium a few sclerotia of a fungus named *Rhizoctonia destruens* Tass., certain Indian host plants of which were recorded by Shaw and Ajrekar in 1915 (16). The supposed *R. destruens* sclerotia have been compared in bulk and in microtome sections with those of *S. Rolfsii* and have been found to be indistinguishable from the latter, and there is little doubt that the fungus called *R. destruens* in India and the Ceylon *S. Rolfsii* are identical. In all probability the Indian fungus was misnamed.

The *Sclerotium Rolfsii* of this paper is indistinguishable from *Sclerotium zeylanicum* (B. and Br.) Petch which is represented in Herb. Kew (Petch No. 6472) and in Herb. Peradeniya (Nos. 6472, 3736, 4876). Petch's combination appears to have been founded on *Tuber zeylanicum* B. and Br. (Fungi of Ceylon, 1873, No. 975), the types of which in Kew Herbarium (Thwaites No. 1013) and at Peradeniya shew an internal structure which differs from that of the sclerotium of both *Rolfsii* and *zeylanicum* and is suggestive of the *Tuberaceae*. Petch's combination may therefore be incorrect. In any case, *Sclerotium Rolfsii* dates from 1911 (17) and *S. zeylanicum* from 1923 (18). *S. zeylanicum* (B. and Br.) Petch may therefore be known as *S. Rolfsii* Sacc.

I have to thank Messrs. Ashby and Mason of the Imperial Bureau of Mycology for an examination of the type of *Tuber zeylanicum* in the Kew Herbarium and Dr. W. Small, M.B.E., Mycologist, Department of Agriculture, Ceylon, for help in the preparation of this paper.

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EXPLANATION OF PLATES

Plate XXI

- Fig. 1. Sclerotia and hyphae on leaf and stem of groundnut in nature. Nat. size.
- Fig. 2. Single sclerotia and aggregations of sclerotia formed on dadap leaf soaked in sugar solution and sterilised. Nat. size.
- Fig. 3. Sclerotia formed on sterilised sweet potato. Nat. size.
- Fig. 4. Sclerotia formed on dadap leaf sterilised by boiling. $\times \frac{6}{7}$.

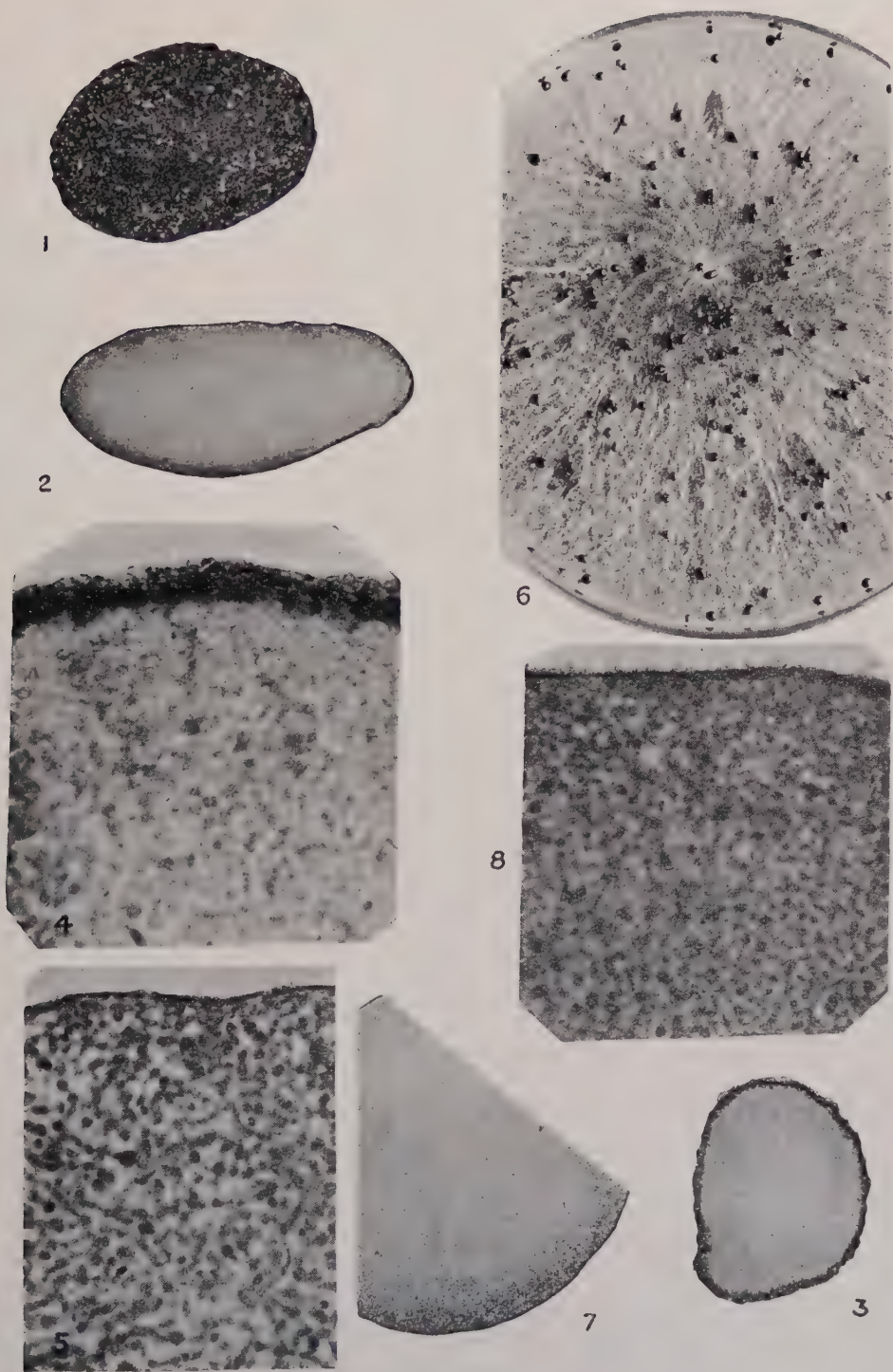
Plate XXII

- Fig. 1. Section of sclerotium in nature. $\times 56$.
- Fig. 2. Section of sclerotium on sterilised potato slab. $\times 21$.
- Fig. 3. Section of sclerotium on sterilised potato slab. $\times 40$.
- Fig. 4. Same as Fig. 2 but $\times 140$.
- Fig. 5. Same as Fig. 1 but highly magnified.
- Fig. 6. Sclerotia on bacto-prune agar. Nat. size.
- Fig. 7. Section of sclerotium on maize-meal agar. $\times 34$.
- Fig. 8. Same as Fig. 7 but highly magnified.

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Sclerotium Rolfsii on Ground Nut



Sclerotium Rolfsii Sacc.



On the Parasitism of *Sphaerostilbe repens* B. and Br.

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WITH TWO PLATES

Sphaerostilbe repens was collected by Thwaites at Peradeniya on decaying jak (*Artocarpus integrifolia*) wood and was described and named by Berkeley and Broome (1) about fifty years ago. Since its discovery it has been encountered in Ceylon and other parts in association with root disease of various plants. In 1907 Petch recorded it as the cause of a root disease of *Hevea*, and in 1910 he published an account (2) of the disease in which he stated that, in the case of the death of three large twenty-five-year-old rubber trees, the *Sphaerostilbe* entered damaged roots, and that, in other cases, *Sphaerostilbe* disease appeared to be most common in swampy or sour soil. It was reported, however, to have killed two-year-old rubber trees in average plantation soil and to have been undoubtedly parasitic on the rhizome of arrowroot (*Maranta arundinacea*). At later dates the fungus was recorded on papaw and a decaying dadap log in Ceylon.

In 1919, the junior writer investigated a case of root disease of rubber trees which adjoined an old jak tree. The area of disease was shaded heavily and the soil was usually wet. The base of the stem of the jak tree was covered with conidial fructifications of *Sphaerostilbe repens* and jak roots affected by the fungus were found in contact with rubber roots to which the fungus appeared to have passed. Conidiophores were found also on exposed lateral roots of the rubber. In a case of

rubber root disease at Peradeniya, *Sphaerostilbe* and *Ustilina zonata* had attacked affected trees. Certain lateral roots showed only the mycelial strands of *Sphaerostilbe* and others only *Ustilina*, while other roots and the collar region of one of the trees were affected by both fungi. In 1924 *Sphaerostilbe* was found in association with root disease of jak and breadfruit (*Artocarpus incisa*) trees which were growing in wet soil at Mutwal. The fungus has been classed as the cause of a primary root disease of rubber in Ceylon by Mitchell (3).

With regard to Malaya, Brooks has stated (4) that, in the case of rubber affected by *Sphaerostilbe*, the fungus advanced into living tissues and therefore acted as a parasite. His inoculation experiments, however, were negative in results, and he suggested that a predisposing cause was required to enable the fungus to enter the plants. Its subsequent passage into healthy tissues was attributed to its parasitism. In 1917 Belgrave (5) stated that *Sphaerostilbe* disease of rubber occurred on low-lying lands. Rhind (6) has recorded the presence of the fungus on dead jungle stumps and rubber wood in Burma, but he noted that it had not been seen on living rubber, while Weir (7) who made a pathological survey of the rubber tree in the Amazon Valley stated that *Sphaerostilbe* was not found for a certainty in that region. In recording the fungus on rubber in the Dutch East Indies Steinmann (8) said that it usually occurred saprophytically on decaying roots in badly-drained land.

Tunstall (9) stated recently that *Sphaerostilbe* was occasionally found in North East India on the roots of vigorous and apparently healthy tea bushes, an observation that has not been made in Ceylon, and that the roots of jak trees infected by the fungus did not appear to suffer serious harm. The presence of a *Sphaerostilbe* (probably *S. repens*) on the roots of limes affected by dieback has been recorded from the Gold Coast, and Nowell (10) has given an account of *Sphaerostilbe* (now known to be *S. repens*) or red root disease of limes in the West Indies concerning which he has said that the Dominica and Ceylon (*Sphaerostilbe*) diseases agree in their restriction on the whole to swampy or sour undrained soil.

During the years 1926 and 1927 *Sphaerostilbe repens* has been recorded in Ceylon by the Mycological Division of the Department of Agriculture on mature rubber, young rubber stumps, tea, *Acacia*, jak, dadap, papaw, cacao and stumps of red gum (*Eucalyptus* sp.). In several cases, the presence of the fungus could be correlated to damp or sour soil conditions; in others the host plants were growing under normal conditions. In all cases, again, in which investigation could be pursued beyond the usually incomplete and unsatisfactory specimens submitted for examina-

tion, it has to be recorded that a second fungus, *Rhizoctonia bataticola*, was found to be present in such circumstances that it was likely that the *Rhizoctonia* not only accompanied but also preceded the *Sphaerostilbe* in time of attack. The *Rhizoctonia* has been noted to be present even in cases where the degeneration or unhealthy condition of roots required to enable the *Sphaerostilbe* to attack seemed assured by their environment, for example, roots growing in permanently wet or swampy soil. *Sphaerostilbe* on tea roots is uncommon in Ceylon; in the only case that has been encountered in the last two years *Rhizoctonia bataticola* was also present.

In January, 1927, the junior writer had occasion to examine a papaw plant which was affected by a soft rot at soil level. The tree had borne fruit and the leaves had fallen one by one; there remained only a small tuft of green leaves at the apex of the stem. In the rotted tissue of the collar of the plant reddish rhizomorphs of *Sphaerostilbe* formed a tangled mass and also extended into the healthy stem tissue. The conidial fructifications of the fungus were borne on the rhizomorphs. They were of the usual form, short, erect, reddish stalks, 5–8 mm. in height, with white globose heads of 1–1.5 mm. diameter. The conidia were oval, hyaline, apiculate at one end or rounded at both ends, and they measured $12\text{--}21 \times 6\text{--}10\mu$. No perithecia were found. As the roots of the plant had rotted or had been eaten by termites, the presence or absence of other fungi than the *Sphaerostilbe*, for example, *Rhizoctonia*, could not be determined. Owing to heavy shade and the presence of a large pile of firewood, the site of the affected plant was sodden. Pure cultures of *Sphaerostilbe repens* were obtained from the papaw material and were used in the inoculation experiments described below.

It may be added that the senior writer's study of cases of root disease with which *Rhizoctonia bataticola* and *Sphaerostilbe repens* are associated has led him to regard the former fungus as the primary cause of the disease and the latter as of only secondary account. *Sphaerostilbe* is thus placed on a level with certain other supposed primarily parasitic fungi, for example, *Fomes* and *Poria* (11), and it is to be noted that Briton-Jones (12) says with reference to red root disease of lime in the West Indies which is attributed to *Sphaerostilbe repens* that *Sphaerostilbe* is not the primary cause of the disease. He does not imply, however, that *Rhizoctonia bataticola* is the primary cause in the sense that it is present and precedes the *Sphaerostilbe* in time of attack; he means that certain external or environmental conditions conduce to *Sphaerostilbe* attack. It may also be noted that records of experimental tests of the parasitism of *Sphaerostilbe* are few, in fact, only one in number, that conducted by Brooks in Malaya.

CULTURES

Pure growths of *Sphaerostilbe* were obtained from single conidiophores, from conidia in the mass, from the inner tissue of rhizomorphs and also from single conidia. Spores were germinated in water and the fungus was grown on maize meal, lima bean and prune agars, on rubber roots, and on pieces of rhizome of arrowroot and *Canna*.

Spore germination (Plate XXIV., fig. 7). In drops of distilled water the conidia germinated in some cases in nine hours and in others in fifteen hours. The majority of the conidia in a culture germinated in nineteen hours. The germ tubes were hyaline, non-septate, 3-4 μ in diameter and 80-140 μ in length. They anastomosed frequently and the tip of a germ-tube which encountered a spore united with the spore. As a rule, the germ-tubes arose from an end of the spore, particularly an apiculate end when it was present, and they arose singly from each spore, but in a culture drop a few spores could be found to have extruded germ-tubes from both ends after forty-eight hours.

Maize meal cultures (Plate XXIII., figs. 1-2 ; plate XXIV., figs. 1-6). After three days a deep salmon-pink colour developed at the point of inoculation and conidiophores were formed on the surface of the medium. White hyphae spread to a distance of 5 mm. from the coloured patch and white rhizomorphs developed in the medium. In mono-spore cultures it was noted that the formation of rhizomorphs was followed immediately by the production of conidiophores on the rhizomorphs. The salmon-pink colouration was due to the colouring of the clusters of conidiophores. In another twenty-four hours the mycelium on the surface of the medium around the original point of inoculation became yellow-brown in colour through the formation of numerous brown chlamydospores. The hyphae which continued to advance from the point of inoculation remained hyaline and moved through a distance of 25 mm. in another six days. At this point white globose heads or masses of spores were formed on the conidiophores. After a further ten days the superficial growth was a mixture of olive-brown and reddish-brown colour and the rhizomorphs continued their growth and reached the bottom of the culture tube. The rhizomorphs were red-brown in colour, pointed and less deeply coloured at the apices, and often forked or divided into as many as six prongs. The rhizomorphs came to the surface of the medium at times. They then assumed a deep orange colour and were 4-6 mm. in height and about .5 mm. in diameter ; they formed spore masses at their apices and thus functioned

as conidiophores. When the medium dried up, the rhizomorphs persisted and adhered to the tube.

The advancing hyphae were hyaline and $4-5\mu$ in diameter. Branch hyphae lay almost parallel to the parent hyphae. Anastomosis was common between adjacent hyphae. The hyphae of the red-brown superficial felt of mycelium were hyaline or pale brown in colour, septate and $4-6\mu$ in diameter; they produced numbers of brown chlamydospores. The point of origin of a branch hypha was often constricted. The chlamydospores of the superficial mycelium germinated to give more chlamydospores, a process which was repeated again and again. Chlamydospores were formed terminally on main and branch hyphae. The submerged hyphae were hyaline, thin and sparse; they formed chlamydospores apically and intercalary but in small numbers. At times the chlamydospores were formed on short lateral branches on both sides or only on one side of the parent hypha.

Lima bean cultures. Growth on lima bean agar differed from growth on the maize meal medium in the lighter yellow-brown colour of the older mycelium and in a slower development of the rhizomorphs. It was noted that the contamination of the culture tubes with bacteria prevented superficial growth of mycelium, but did not retard the growth of the rhizomorphs within the medium.

Prune cultures. Growth in prune agar was similar to that recorded for maize meal but was less luxuriant. On the whole, maize meal was a more suitable nutrient for the fungus than either lima bean or prune extract.

The perithecial stage of the *Sphaerostilbe* did not appear on the media mentioned above, and attempts were therefore made to obtain it on *Hevea* root tissue and rhizomes of arrowroot and *Canna*.

Hevea root blocks (Plate XXIII., figs. 3-5). Pieces of healthy *Hevea* roots measuring 4 inches in length and 1 inch in diameter were sterilised, partially buried in moist sterilised sand in glass dishes and inoculated with pieces of the above media containing mycelium or with conidia in water. The blocks were covered with red-brown conidiophores in five days and conidia were produced in abundance. Rhizomorphs were formed later on the surfaces of the blocks, the edges of which they overran. They also branched apically and formed conidia at the tips of the branches. In Roux tubes the *Sphaerostilbe* formed fertile conidiophores and rhizomorphs on *Hevea* root blocks. The wood cultures were kept under observation for over six months, but no perithecial formation was observed.

Arrowroot rhizome. Fertile conidiophores developed in growths on a small proportion of pieces of arrowroot rhizome kept under moist conditions in dishes and Roux tubes for over three months. No perithecia were found.

Canna rhizome. Growth on *Canna* rhizome was less successful than that on arrowroot rhizome for conidiophores were formed on only one piece out of five. No perithecia were observed.

INOCULATIONS

Dadap (*Erythrina lithosperma*). Inoculations were made on the roots of two full-grown dadaps, the branches of which were large and dense enough to shade the soil occupied by the inoculated roots. In addition, water was poured on the soil on days on which no rain fell during the time of the experiments. The inoculations were made in wet weather at the beginning of June, 1927; the inoculum consisted of pieces of agar medium containing active growths of the fungus. In the case of one of the trees, the fungus was placed in contact with two roots, one of which was .5 and the other 1 inch thick, at points where wounds had been made by cutting out small pieces of the cortical tissue at intervals of .1 inch for a space of 1 inch. The inoculum was kept in contact with the wounded root tissue by a pad of moist cotton-wool held in position with waxed tape. In the case of the second tree, a root .75 inch thick and two groups of small roots were inoculated without wounds.

The inoculated roots were examined after the lapse of eight and a half months. The decayed remains of the waxed tapes were then *in situ*, but no infection had taken place.

Tea (*Thea sinensis*). Similar inoculations were made on tea roots in the field in May and June, 1927. The inoculum consisted of fragments of maize meal medium containing the fungus and of growths on *Hevea* root blocks. The latter bore numerous fertile conidiophores and were permeated by mycelium; they were placed in close contact with the inoculated portion of the plant and were held in position with a binding of twine. In the case of bush No. 3 of the accompanying Table, inoculations were made by inserting the cut ends of roots in tubes containing active cultures of the fungus. After inoculation disturbed soil was replaced, and the areas containing inoculated roots were watered daily for a month.

Table : tea inoculations

<i>Bush No.</i>	<i>Treatment</i>	<i>Inoculum</i>	<i>Point of Inoculation</i>	<i>No. of Inoculations</i>	<i>Remarks</i>
1	{ Without wounds	<i>Hevea</i> blocks	Large and small roots	2	Examined 9/2/28 ; no infection.
2	{ With wounds	"	"	2	"
3	"	Culture	"	6	Examined 3/2/28 ; no infection.
4	"	"	"	2	"
5	{ Without wounds	"	Collar	1	"
6	{ With wounds	"	"	1	"
7	{ Without wounds	<i>Hevea</i> blocks	Collar and small roots	1	Examined 9/2/28 ; no infection.
8	"	"	"	1	"
9	"	Culture	Large and small roots	2	Examined 3/2/28 ; no infection.
10	{ With wounds	Culture medium without fungus	"	3	Control ; healthy.
11	{ Without wounds	"	"	2	" "
12	"	<i>Hevea</i> blocks	Collar ; large, small and very small roots	1	Examined 13/2/28 ; no infection.
13	"	"	"	1	"

It will be noted that eleven bushes were subjected to inoculation and that results were entirely negative. In many cases inoculation wounds healed, and in bush No. 3 clusters of small healthy roots developed behind the points of amputation of the roots and filled the culture tubes containing the inoculum. The fungus on the *Hevea* blocks formed typical black rhizomorphs on the wood of the blocks.

Rubber (*Hevea brasiliensis*). The roots of six full-grown rubber trees were used in experiment. The inoculum and its treatment were similar to those of the dadap experiments, and the ground was watered in the same way. When inoculations were made with wounds, narrow

longitudinal strips of root cortex were removed and extra cuts were made at right angles to the first longitudinal cut. The wounds were cleared of latex before the inoculum was placed in contact with the tissues. In certain cases, the wounds were washed with methyated spirit, lightly flamed and then washed with distilled water before inoculation.

In tree No. 1, three wound inoculations were made on roots of 2, 3 and 7 inches circumference respectively at a short distance from the collar of the tree. The inoculum consisted of agar medium containing the fungus. After ten months no infection had occurred and the root wounds had healed. In tree No. 2 non-wound inoculations were made on three roots, one large and two small, and on a bunch of very small roots by placing pieces of culture medium and *Hevea* blocks in contact with the roots. After eleven months examination showed that no infection had taken place. In tree No. 3 three root wounds were treated with the fungus in culture and *Hevea* root blocks were also tied to the roots. After ten months examination showed that no infection had taken place. The *Hevea* blocks had rotted away. In tree No. 4, a large root of 5 inches diameter was inoculated in a wound with the fungus in culture and *Hevea* blocks containing the fungus were also placed in contact with the root. Ten months were allowed to elapse before the points of inoculation were examined; it was found then that no infection had taken place and that the wound had formed a callus around its edges from which small roots were produced. In tree No. 5, a root of 7 inches circumference was cut at a distance of 20 inches from its point of origin. The cut surface was flamed and the root was treated in the same manner as tree No. 4. After the lapse of twelve months it was found that a cluster of small roots had been produced from the root at a point behind the cut and that no infection had taken place either on the cut or elsewhere. In tree No. 6, a root of about 10 inches circumference was sawn through and the cut surface was inoculated with the fungus in culture. The inoculated root was partly covered with soil and partly with a flower pot. The cut surface was examined after ten months, and it was found to be covered with a thin felt of mycelium. The root, however, had formed a cluster of small roots behind the cut. Internal examination of the root disclosed a discoloured area which extended inwards from the cut for a distance of .5 to 1.5 inches and which was bordered by a brown margin. Hyphae were present in the margin of the discoloured area and also in thin brown lines which occurred in the discoloured wood. Cultural investigation of the lines and margin showed that they formed a mycelium which was not that of *Sphaerostilbe repens*.

Thirteen inoculations in all were attempted on *Hevea* roots and all proved unsuccessful.

Rubber Seedlings. The fungus was introduced into the previously sterilised soil of pots in which seven-months-old rubber seedlings were growing and was placed in contact with roots and collars in the form of growths on *Hevea* blocks and pieces of culture medium. In one series of experiments, the soil of two medium-sized pots was treated with $1\frac{1}{2}$ ozs. superphosphate to render it acid, that of two pots with 1 oz. lime to render it alkaline, and that of other four pots, including two control pots, was untreated. After inoculation the pots were placed in the open under shade and were kept moist. After seven months no infection had taken place; the growth of the seedlings was normal in all pots. In another series, the fungus in culture was placed in contact with rubber seedling roots and collars; in one of the pots the roots exposed to contact with the fungus were bound together with waxed tape. The pots were watered daily for three months; afterwards they were kept in the shade of the plant-house and were watered twice daily during the experiment. No positive infection ensued.

In these experiments twenty-nine seedlings were exposed to the *Sphaerostilbe* without positive result.

Cacao Seedlings (*Theobroma cacao*). Three pots containing fifteen ten-weeks-old cacao seedlings were inoculated by burying in the soil *Hevea* blocks bearing the fungus in quantity. Contact between fungus and roots was assured. The pots were kept in shade either in the open or in the plant-house, and all were kept moist by daily watering. Examination after the lapse of seven months showed that all the seedlings had well-developed root systems, the smallest roots of which had penetrated in many cases the *Hevea* blocks bearing the fungus. No infection was noted.

Arrowroot (*Maranta arundinacea*). Twelve plants growing in pots of sterilised soil were inoculated in the manner of the cacao seedlings. The pots were kept very moist throughout the experiment and were kept in the shade. Only one plant was attacked by the fungus, the upper part of the rhizome in the region of the shoot becoming discoloured while the lower part remained healthy. The diseased tissue contained hyphae of $3-4\mu$ diameter which gave rise to *Sphaerostilbe* conidiophores in a few days on maize-meal agar. Although the rhizomes and roots of other plants were in contact with the fungus, no further disease was observed after seven months. The unattacked plants grew vigorously.

Canna (hort.). *Canna* rhizomes were divided and three pieces were inoculated on the cut surfaces; no external signs of infection were

visible after two weeks. When the same three pieces of rhizomes were planted in sterilised soil, the shoots which they formed died back when they were about 6 inches in height, that is, seven weeks after inoculation. The bases of the shoots and the rhizomes themselves were discoloured, the latter being of a purple-brown colour which became black on exposure. The discoloured rhizome tissue contained typical chlamydospores and also hyphae which were hyaline to light-brown in colour, branched, septate and up to 4μ in diameter. A control plant which was raised from a cut piece of rhizome did not develop disease.

Another rhizome, which was inoculated on an unwounded surface and treated as above, proved to be infected. It exhibited the same symptoms and microscopic characters as the rhizomes of the preceding experiment.

On the other hand, *Canna* plants which were growing in sterilised soil and which were inoculated in the same manner as the cacao seedlings and kept under moist soil conditions for eight months showed no infection.

Papaw (*Carica Papaya*). *Hevea* blocks with active growths of the fungus were placed in contact with the tap-root and lateral roots of a papaw plant of about 4 feet in height. The soil was watered daily for two weeks. After two months latex was seen to ooze from the base of the stem, especially during rain, and the lower leaves of the plant yellowed and fell. Seven months later only a tuft of small leaves remained at the apex of the stem. Examination showed then that no *Sphaerostilbe* infection had occurred on the lateral roots exposed to the fungus. An external cavity and an internal discoloration about 8 cm. in length, however, showed that the tap-root was diseased. The internal discoloured area was bounded by a distinct brown margin which marked off the diseased from the healthy tissue. Hyaline branched hyphae up to 4μ in breadth were present in the discoloured tissue, and fragments of the latter gave rise to conidiophores of *Sphaerostilbe* in culture.

A second larger papaw plant was inoculated in a wound made in the stem just below soil level. After application of the inoculum, a piece of a maize meal culture, the wound was bound up with moist cotton-wool and waxed tape. Oozing of latex at the base of the stem commenced in one week. After three weeks, latex oozed also from two fruits which eventually fell from the plant. Decay of the collar region of the plant set in, and the plant collapsed after three and a half months. Rhizomorphs were present in quantity in the decayed stem tissue, and the

fungus was recovered from the latter with ease. The rhizomorphs were yellow or red-brown in colour, about 2 mm. in thickness, and banded together in sheets of 9 mm. diameter. Internally the rhizomorphs were white in colour and made up of loosely interwoven hyphae which measured up to 9μ in diameter. The cortex was brown in colour and made up of five or six layers of polygonal cells of $10\text{--}15\mu$ diameter. External cells were darker and had thicker walls than internal cells. The cortex was as much as 80μ in thickness.

Another full-grown papaw plant was inoculated with the fungus in contact with the roots. Pieces of agar cultures were used and the inoculum was bound with moist cotton-wool and waxed tape. The roots were examined after seven months had elapsed and were found to be unaffected. The plant remained healthy.

The results indicated that *Sphaerostilbe repens* was able to cause a collar rot of papaw, but that it did not infect lateral roots with readiness. It was possible that the condition of the infected parts before inoculation had been affected by adverse influences, for example, undetected attack of *Rhizoctonia bataticola* on the tap-root or on the lateral roots attached at or near the collar region. On the other hand, the inoculated parts appeared to be perfectly sound and healthy at the time of treatment.

DISCUSSION

The results of the above experiments showed that *Sphaerostilbe repens* was able to attack arrowroot, *Canna* and papaw under the conditions imposed and that it was unable to attack the healthy roots of woody plants like tea, rubber and dadap, or of rubber and cacao seedlings, even with the supposed help of wound entrances to tissues and close contact between inoculum and host surfaces.

From the practical point of view the question of the attack of *Sphaerostilbe* on roots of woody plants is of greater interest than the question of *Sphaerostilbe* disease of arrowroot, *Canna* and papaw, and the remainder of this discussion therefore deals with the woody-plant aspect of the subject in hand. The lack of positive results in experiments with woody plants agrees with the negative results obtained by Brooks in experiments with rubber in Malaya. The investigator is forced thus to the conclusion that successful *Sphaerostilbe* attack on the roots of woody plants is conditioned by the previous operation and effects of adverse physiological conditions which are presumed to produce in the exposed plant such a state of degeneration or lack of resistance that *Sphaerostilbe* is enabled to assume a parasitic rôle. In

nature the adverse conditions seem to be supplied most frequently by lack of drainage and a consequent suffocation of the roots of affected woody plants, and it is possible that a moist or wet soil is the most suitable substratum for *Sphaerostilbe*. On the other hand, it is to be noted that the attempt to imitate natural moist soil conditions in the experiments did not lead to *Sphaerostilbe* attack on woody roots and that the fungus is found in nature in plantation soils which do not suffer from lack of drainage. It is not forgotten that the attempts to imitate moist soil conditions in the experiments may have fallen far short of natural conditions in their results. At the same time, it may be doubted if the moist soil conditions said to be required for successful *Sphaerostilbe* attack are in constant and regular operation in nature.

It is, therefore, in order to enquire into the possible presence and operation of other factors which may cause the necessary preliminary degeneration or unhealthy condition of woody roots required for *Sphaerostilbe* attack, and it has to be reported that, as already mentioned, a root disease factor is present with such frequency in Ceylon cases of *Sphaerostilbe* root disease that it must be taken into account. In short, it is probable that in many cases of *Sphaerostilbe* attack on woody roots, if not in all, the entrance and advance of the *Sphaerostilbe* is preceded by a diseased condition induced by *Rhizoctonia bataticola* attack. The grounds on which the attack of the *Rhizoctonia* is assumed to be prior to that of other fungi found on diseased woody roots have been discussed (11) with reference to *Fomes*, *Poria* and other forms, and they need not be repeated in this place. The writers, therefore, do not deny that *Sphaerostilbe* attack on woody roots may be a secondary phenomenon which follows upon moist or sour soil conditions, but they think it is necessary to lay stress upon the necessity for investigation into the possibility of the presence of *Rhizoctonia bataticola* either with and without the abnormal soil conditions.

It may be added in conclusion that the *Sphaerostilbe* experiments of this paper are part of a larger scheme of work which aims at the testing in experiment of a number of fungi, the accepted parasitism of which is insufficiently supported by experiment or open to question owing to the presence of *Rhizoctonia bataticola*.

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EXPLANATION OF PLATES

Plate XXIII.

Figs. 1 and 2. Rhizomorphs formed in maize-meal agar culture from single conidium. $\times \frac{5}{6}$.

Fig. 3. Conidial fructifications on inoculated *Hevea* root in moist chamber. $\times 1$.

Figs. 4 and 5. Rhizomorphs on inoculated *Hevea* root in moist chamber producing conidia at their apices. $\times \frac{5}{6}$

Plate XXIV.

Fig. 1. Chlamydo-spores in culture from conidia. $\times 950$.

Figs. 2. and 3. Chlamydo-spores germinated in a water culture, 14 days old. $\times 950$.

Fig. 4. Advancing hyphae in culture. $\times 950$.

Fig. 5. Hyphae common in old culture. $\times 950$.

Fig. 6. Typical conidia. $\times 950$.

Fig. 7. Five conidia germinated in water. $\times 950$.

(Received for publication March 16th, 1928.)



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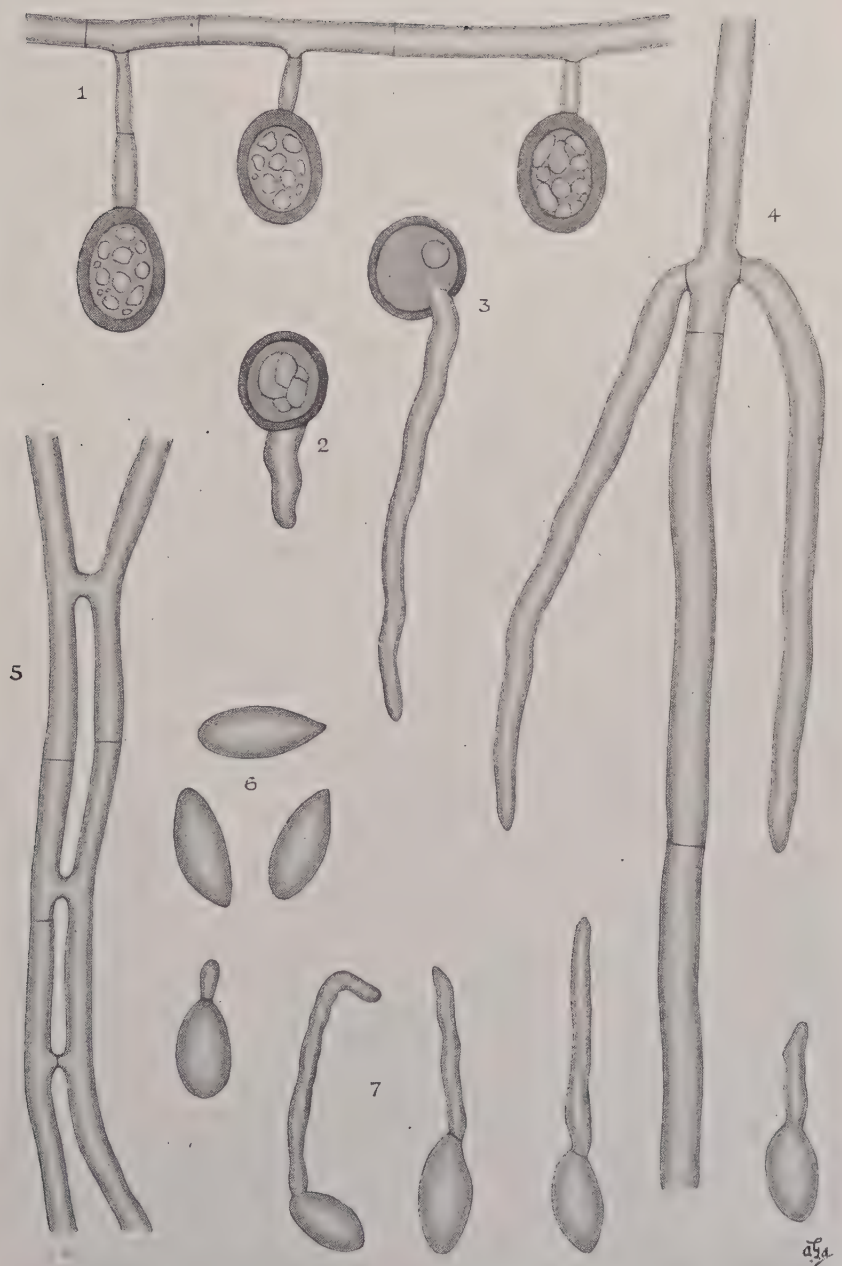
4



5

LJB

Sphaerostilbe repens B. and Br.



Sphae ostilbe repens B. and Br.

Names published in Moon's Catalogue

BY

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C. B. Robinson (1) has pointed out that certain specific names in Roxburgh's *Hortus Bengalensis*, where descriptions and plates are cited, must be regarded as effectively published. This is also applicable to certain names published in Moon's Catalogue of the plants of Ceylon.

New names :—

Exacum connatum Moon p. 11, based on Rheede Mal. 10, t. 52 = CANSCORA PERFOLIATA Lamk. Encycl. I, p. 601 (1783); Clarke in Fl. Brit. Ind. VI., p. 105 (1885). *C. ventricosa* J. F. Gmel. Syst. p. 262 (1788). *Pootia triflora* Dennst. Schlüss. Hort. Malab. p. 37 (1818). *Exacum alatum* Roth. Nov. Sp. p. 85 (1821).

The Jaffna specimen was *C. Roxburghii* Arn.

Pothos elliptica Moon p. 11, based on Rumph. Amb. 5, t. 181, f. 2. = *P. LATIFOLIUS* Linn. in Stickm. Herb. Amb. p. 25 (1754); Merr. Int. Rumph. p. 125 (1917). ? *P. gracilis* Roxb. Fl. Ind. ed. 2, I., p. 433 (1832) non. Engler ? *P. Barberianus* Schott Aroid. I, p. 24 t. 53 (1853); Engler Pflreich. IV, 23B, p. 40 (1905).

Published by citation of Rumph. H. Amb. V, t. 181 f. 2. Linnaeus' *P. latifolius* was also based on the same Rumphian figure. *P. latifolius* Linn. is a doubtful species not mentioned by Engler (2). The Cultura specimen was *P. remotiflorus* Hk. f., an endemic species.

Echites fragrans Moon p. 20, based on Rheed. Mal. 9, t. 56. (5 & 6) = CHONEMORPHA FRAGRANS (Moon). *C. macrophylla* G. Don. Gen. Hist. IV, p. 76 (1836). *Echites macrophylla* Roxb. Hort. Beng. p. 20 (1814) nomen; Fl. Ind. II, p. 13 (1824) non. H.B.K. (1819).

E. laevigata Moon p. 20, based on Rheed. Mal. 9, t. 9. = PARSONSIA LAEVIGATA (Moon). *Helygia javanica* Bl. Bijdr. p. 1043 (1826). *Parsonsia ovata* Wall. Cat. no. 1630 (1828) nomen. *P. spiralis* Wall. l.c. no. 1631 (1828) nomen; A. DC Prodr. VIII, p. 402 (1844). *P. javanica* K. Sch. in Engl. u. Prantl. Nat. Pfl. IV, 2, p. 184 (1895) non Blume (1826).

Hoya reticulata Moon p. 21, based on Rumph. Amb. 5, t. 40 = GYMNEMARETICULATA (Moon). *Gymnema syringaeifolium* Boerl. Handl. Fl. Ned. Ind. II, p. 437 (1899); Const. in Lec. Fl. Gen. Indo-China IV, p. 86 (1912); Merr. Int. Rumph. p. 435 (1917). *Bidara syringaeifolia* Dene. in DC. Prodr. VIII, p. 623 (1844).

Apocynum reticulatum Willd. [Sp. Pl. II, p. 1261 (1800)] is added with a ? *Apocynum reticulatum* Linn. Sp. Pl. p. 214 (1753) is a doubtful species not given in the Fl. Brit. Ind.

Adenanthera bicolor Moon p. 34, based on Rumph. Amb. 3, t. 112 = PITHECOLOBIUM CLYPEARIA Benth. in Hk. Lond. Journ. Bot. III, p. 209 (1844). ? *Inga clypearia* Jack. Mal. Misc. II, p. 78 (1822). *Mimosa trapezifolia* Roxb. Hort. Beng. p. 93 (1814) nomen; Fl. Ind. ed. 2, II, p. 78 (1822), non *Pithecolobium bicolor* Benth. (1897).

The plant now known as *A. bicolor* may be known as *Adenanthera aglaosperma* nom. nov.

Eugenia sylvestris Moon p. 38, based on Wal-jambu Burm. zeyl. p. 125 (err. 6) = SYZYGIUM AQUEUM (Burm. f.) *Eugenia aquea* Burm. f. Fl. Ind. p. 114 (1768). *Jambosa aquea* DC. Prod. III, p. 288 (1828).

Ochna grandiflora Moon p. 41, based on Roxb. Cor. 1, t. 89 = O. SQUARROSA Linn. Sp. Pl., ed. 2, p. 731 (1762), excl. syn. Burm.

Dalbergia filiformis Moon p. 51, based on Rheed. Mal. 6, t. 22 = DERRIS SCANDENS Benth. in Journ. Linn. Soc. IV, Suppl. p. 103 (1860). *Dalbergia scandens* Roxb. Cor. Pl. II, p. 192 (1798).

Phyllanthus pomacea Moon p. 64, based on Rheed. Mal. 5, t. 43 = BREYNIA RETUSA (Dennst.). *Phyllanthus retusus* Dennst. Schlüss. Hort. Mal. p. 31 (1818). *P. turbinatus* Koen. ex Roxb. Fl. Ind. III, p. 666 (1832). *P. patens* Roxb. l.c. p. 667. *Breynia patens* Benth. in Gen. Pl. III, p. 277 (1883); Trim. Fl. Ceyl. IV, p. 33.

New combinations :—

Alpinia Granum paradisi Moon p. 1, based on *Amomum granum paradisi* Willd. and Rheed. H. Mal. 9, t. 6 = AMOMUM GRANUM PARADISI Linn. Sp. Pl. p. 2 (1753). *Aframomum granum paradisi* K. Sch. Zingiberaceae in Engl. Pflreich. IV, 46, p. 413 (1904).

The Kandy plant was *Elettaria major* Sm.

Ichnocarpus paniculatus Moon p. 20.

Moon cites *Apocynum paniculata* Willd. [Sp. Pl. II, p. 1261 (1800), *paniculatum*] with a ?. This is FORSTERONIA ACOUCI A. DC. in DC. Prodr. VIII, p. 439 (1844). *Apocynum Acouci* Aubl. Pl. Guian. I, p. 274 (1775). *Apocynum paniculatum* Lamk. Encycl. I, p. 214 (1783).

The Colombo plant was *Anodendron paniculatum*.

Daemia reticulata Moon p. 30, based on *Cynanchum reticulatum* Willd. [Sp. Pl. II, p. 1158 (1800)] = LEPTADENIA RETICULATA W. &

A. Contrib. p. 47 (1834). *Cynanchum reticulatum* Retz. Obs. II, p. 15 (1751).

M. vomitoria Moon p. 21, based on *Asclepias vomitoria* Koen. = TYLOPHORA INDICA Merr. in Phil. Journ. Sci. XIX, p. 373 (1921). *Cynanchum indicum* Burm. f. Fl. Ind. p. 70 (1768). *Asclepias asthmatica* Linn. f. Suppl. Pl. p. 171 (1781). *Tylophora asthmatica* W. & A. Contrib. p. 51 (1834).

I cannot find out where *A. vomitoria* Koen. was published.

Marsdenia tenacissima Moon p. 21, based on *Asclepias tenacissima* Roxb. Cor. Pl. 3, t. 240 = M. TENACISSIMA W. & A. in Wight. Contrib. p. 41 (1834).

Hoya alexicaca Moon p. 21, based on *Asclepias alexicaca* Willd. [Sp. Pl. II, p. 1270 (1800) pp. non Jacq. (1786)] and Rheed. Mal. [IX], t. 13 = TYLOPHORA PAUCIFLORA W. & A. ?

Trimen (3) considered Moon's specimen to be *Cynanchum pauciflorum* R. Br.

Clerodendron serratum Moon Cat. p. 46, based. on *Volkameria serrata* Linn. [Mant. p. 90 (1767)], and Rheed. Mal. 4, t. 29 = C. SERRATUM Spreng. Syst. II, p. 758 (1825).

Aerides tenuifolium Moon p. 60, based on Rheed. Mal. 12, t. 5, and *Cymbidium tenuifolium* Willd. [Sp. Pl. IV, p. 103 (1806)] = SACCOLABIUM TENUIFOLIUM (Linn.) *Epidendrum tenuifolium* Linn. Sp. Pl. p. 952 (1753). *Sarcanthus peninsularis* Dalz. in Kew Journ. Bot. III, p. 247 (1867).

Cymbidium spathulatum Moon p. 60, based on Rheed. Mal. 12, t. 3. *Limodorum spathulatum* Willd. [Sp. Pl. IV, p. 725 (1806)] = VANDA SPATHULATA Spreng. Syst. III, p. 719 (1826). *Epidendrum spathulatum* Linn. Sp. Pl. p. 1348 (1753).

Diceros aquaticus Moon p. 45, based on *Cyrilla aquatica* Roxb. [Cor. Pl. II, p. 189 (1798)] = LIMNOPHILA AQUATICA (Moon). *Limnophila racemosa* Benth. Scroph. Ind. p. 26 (1835).

Stizolobium giganteum Moon p. 53 ; Spreng. Syst. IV, based on *Dolichos giganteus* Willd. [Sp. Pl. III, 2, p. 1041 (1803)], and Rheed. Mal. 8, t. 35 = MUCUNA GIGANTEA DC. Prodr. II, p. 405 (1825).

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The Flora of Maragalakande

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Maragala or Monaragala is an isolated mountain in the Province of Uva. It is 3,648 ft. high and its vegetation is of considerable interest as many species reach their eastern limit there.

The mountain was visited on March 5th, 1928, and the following species noted above 2,000 ft.

In the Jungle

- Uvaria macropoda* Hk. f. & Th.
Artabotrys uncinatus Baill. (*A. odoratissimus* R. Br.)
Hyserpa cuspidata Miers. (*Limacia cuspidata* Hk. f. & Th.)
Scolopia Schreberi J. F. Gmel. (*S. Gaertneri* Thw.)
Calophyllum sp.
Durio zeylanicus Gardn. (*Cullenia excelsa* Wight)
Pterospermum canescens Roxb. (*P. suberifolium* Lamk.)
Micromelum minutum W. & A. (*M. pubescens* Blume)
Filicium decipiens Thw.
Mappia ovata Miers
Salacia reticulata Wight
Tetragium muricata Gamble (*Vitis lanceolaria* Trim. non Wall.)
Nephelium Longana Camb.
Harpullia arborea Radlk. (*H. imbricata* Thw.) ?
Meliosma Arnottiana Walp. ?
Mangifera zeylanica Hk. f. form with acuminate leaves ?
Semecarpus obscura Thw.
Nothopegia Beddomei Gamble (*N. Colebrookiana* Trim. non Blume)
Connarus monocarpus Linn. ?
Dalbergia pseudo-Sissoo Miq. (*D. Championii* Thw.)
Derris scandens Benth.
Carallia brachiata Merr. (*C. integerrima* DC.)
Syzygium zeylanicum DC. (*Eugenia spicata* Lamk.) broad-leaved form.

- Eugenia rotunda* Trim. ?
Memecylon sp.
Alangium sp.
Uncaria Thwaitesii Alst. (*U. dasyoneura* var. *Thwaitesii* Hk. f.)
Hedyotis marginata Thw. (*H. Lessertiana* var. *marginata* Trim.)
Ophiorrhiza mungos Linn.
Knoxia platycarpa Arn.
Canthium campanulatum Thw.
Psychotria Gardneri Hk. f.
Psychotria sp.
Lasianthus oliganthus Thw.
Ardisia missionis Wall.
Palaquium grande Engl. var. *angustatum* Trim. ?
Symplocos spicata Roxb.
Linociera albidiflora Clarke
Rejoua dichotoma Gamble (*Tabernaemontana dichotoma* Roxb.)
Aganosma cymosa G. Don
Fagraea zeylanica Thunb.
Solanum ferox Linn.
Vitex pinnata Linn. (*V. altissima* Linn. f.)
Heckeria umbellata Kunth (*Piper subpeltatum* Willd.)
Myristica dactyloides Gaertn. (*M. laurifolia* Hk. f. & Th.)
Hortonia floribunda Wight broad-leaved variety.
Cinnamomum multiflorum Wight
Actinodaphne stenophylla Thw.
Neolitsea involucrata Alst. (*Laurus involucrata* Vahl, *Litsea zeylanica* Nees.)
Cleistanthus patulus Muell. Arg. ?
Glochidion stellatum Bedd. (*G. rigidum* Muell. Arg.)
Mallotus philippinensis Muell. Arg.
Macaranga peltata Muell. Arg.
Ficus altissima Blume ?
Ficus Tsjakela Burm. ?
Ficus Thwaitesii Miq. large-leaved form.
Procris laevigata Blume
Dendrobium macrostachyum Lindl.
Languas speciosum Small (*Alpinia nutans* var. *senicea* Trim.) ?
Anomum masticatorium Thw.
Caryota urens Linn.
Calamus Thwaitesii Becc. ?
Calamus pseudo-tenuis Becc. ?
Pothos remotiflorus Hk.

- Cyrtococcum oxyphyllum* Stapf (*Panicum pilipes* Nees & Arn.)
Dryopteris calcarata O. Ktze.
Dryopteris recedens O. Ktze.

Margin of Jungle

- Ouratea zeylanica* Alst. (*Ochna zeylanica* Lamk., *Gomphia angustifolia* Vahl)
Dolichos biflorus Linn. (*D. uniflorus* var. *glaber* Thw.)
Melothria perpusilla Cogn. (*Zehneria Hookeriana* Arn.)
Melothria heterophylla Cogn. (*Zehneria hastata* Miq.)
Mikania scandens Willd.
Microglossa zeylanica Clarke
Argyrea coacta Alst. (*A. populifolia* var. *coacta* Clarke)
Solanum torvum Sw.
Solanum indicum Linn.
Lantana aculeata Linn.
Dioscorea spicata Roth.
Scleria lithosperma Sw. var. *Roxburghii* Clarke.

On patanas

- Polygala leptalea* DC.
Polygala telephioides Willd.
Dodonaea viscosa Linn.
Crotalaria calycina Schrank. var. *anthylloides* (Don)
Crotalaria Bidiei Gamble (*C. rubiginosa* Trim. pp.)
Tephrosia tinctoria Pers.
Pycnospora lutescens Schindl. (*P. hedysaroides* R. Br.)
Desmodium triflorum DC.
Cantharospermum rugosum Alst. (*Atylosia rugosa* W. & A.)
Cassia mimosoides Linn.
Careya coccinea A. Chev. (*C. arborea* Roxb.)
Osbeckia Wightiana Bth.
Vernonia albicans DC.
Hemidesmus indicus R. Br.
Tylophora tenuissima Wight
Tylophora indica Merr. (*T. asthmatica* W. & A.)
Exacum macranthum Arn.
Evolvulus alsinoides Linn.
Leucas sp.
Habenaria cubitalis R. Br.
Arundinella villosa Arn.

EDITORIAL NOTE.

The Annals of the Royal Botanic Gardens, Peradeniya, while retaining its present title, will, from Volume IX, form Section A (Botany) of the Ceylon Journal of Science. Although the Annals will appear in future in this new form, there is no break in the series, and no change editorially or in other essential respects.

It is particularly requested, therefore, that all gifts of literature which hitherto have been made to the Department of Agriculture, Ceylon, in exchange for the Annals should still be continued. All communications with regard to exchanges or any matter arising out of the present publication should be addressed to

**The Director of Agriculture,
Peradeniya, Ceylon.**

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